The Run II Luminosity Upgrade
at the Fermilab Tevatron

v2.0 Project Plan and Resource-Loaded Schedule

January 30, 2004

For the next several years, Fermilab will continue to maintain its pre-eminent position in the world of High Energy Physics with a unique opportunity to make unprecedented studies of the top quark and major discoveries. The goal of the Run II Luminosity Upgrade Plan is to maximize this potential by delivering high integrated luminosities through a program of upgrades to the accelerator complex. This document contains an updated summary of the project plan for the Run II Luminosity Upgrades at the Fermilab Tevatron. It provides a brief review of the project plan, a synopsis of the technical progress since the DOE review in July 2003 and an updated resource-loaded plan for the upgrades.

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Executive Summary

This document provides a comprehensive summary of the Run II Luminosity Upgrade Plan for the Fermilab accelerator complex for the years 2003-2009. The goal of the Run II upgrade program is to deliver the maximum possible integrated luminosity to the collider experiments, CDF and DØ, consistent with available resources. The motivation and technical basis for the upgrade plan was initially described in "Plans for Tevatron Run IIb," presented to the Accelerator Advisory Committee in December 2001. A detailed plan for the upgrades, based on the technical progress and operational experience since the start of Run II, including a resource-loaded schedule, was developed and presented at the DOE review in July of 2003 (v1.0). The v1.0 document also outlined the maintenance projects and a list of major milestones for tracking progress and decision points. This document is the updated version (v2.0) of that plan. It includes a plan for completing the commissioning of the Recycler and integrating the Recycler with electron cooling into operations. The document also describes technical progress made on the Run II upgrade sub-projects, throughout the complex, since July 2003.

The upgrade plan is designed to deliver increasing luminosity in the short-term, while implementing and commissioning a program of upgrades to the accelerator complex to provide significant increases in the future. The upgrade tasks are appropriately integrated with near-term operational planning, and with the plans for maintenance and increased reliability.

The plan for commissioning the Recycler and Electron Cooling, and their integration into operations, is an important component of this v2.0 of the Run II plan. The timely integration of the Recycler project is critical for meeting the schedule and luminosity performance goals. The new Recycler plan and its impact on the projections for integrated luminosity have been evaluated, based on current operational experience, and included here.

Based on the plan described in this document, we expect the integrated luminosity for FY 2004 to be in the range 0.23 to 0.31 fb^{-1} ("base" and "design"), where both numbers include the effects of planned diversion of antiprotons to support Recycler commissioning activities, referred to as the "antiproton tax." The total data sample for physics at the end of FY 2004 will be about twice that available at the start of the fiscal year. Our present *design* and *base* estimates for accumulated integrated luminosity through FY 2009 are, respectively, 8.5 fb^{-1} and 4.4 fb^{-1}, for each of the collider experiments, essentially unchanged from v1.0.

1. Introduction

Fermilab will remain the High Energy Physics Laboratory at the energy frontier until the LHC begins to operate, late in the decade, and LHC experiments start producing competitive physics results. Therefore, Fermilab has the unique opportunity for the next several years to make major advances in the study of the intriguing top quark that was discovered here in 1995. The Lab also has a great potential to make major discoveries including new phenomena beyond the Standard Model of particle physics. A rich harvest of standard model precision physics is guaranteed and new insights and surprises are likely, with the unprecedented amounts of data that Run II offers at the highest collision energy ever studied (Ref. 1, 2). It is of utmost importance, therefore, that Fermilab Run II Luminosity Upgrade Program maximizes the integrated luminosity delivered to the CDF and DØ experiments, during the period before the LHC experiments at CERN begin to produce competitive physics results. The plan that was initially presented at the July 2003 review (and now updated) represents Fermilab's strategy for achieving this goal. The plan consists of individual upgrades to the accelerators, consolidated into one Work Breakdown Structure (WBS) to allow integrated management.

The motivation and the technical basis for the plan were described in "Plans for Tevatron Run IIb" (Ref. 3). The plan was presented to the Accelerator Advisory Committee in December 2001 and at the DOE review in October 2002 (Ref. 4). The DOE review committee requested Fermilab to prepare a detailed, resource-loaded project plan for completing the Run II Luminosity upgrade. In response to that, the "Run II Luminosity Upgrade Plan: Project Plan and the Resource-Loaded Schedule," (Ref. 5) was prepared and presented at the DOE review (Ref. 6) in July 2003. This document was based on the significant technical progress made both in modeling of the performance of the accelerator complex and in planning of the individual sub-projects. That document will be referred to as the version 1.0 (v1.0) document, hereafter. This version 2.0 (v2.0) is an update of that upgrade plan including the Resource-Loaded Schedule (RLS). A set of Technical Notes were provided as an update on the status of the performance modeling and the subprojects at the July 2003 review (Ref. 6).

In this document, we summarize the project elements, organization, technical progress and resource-loaded schedule and include updated luminosity projections. The management procedures, including the process of decision making and reporting, are described in the Appendix. Technical Progress made on several fronts in the various upgrade sub-projects in the past six months (since v1.0) are summarized in Section 2. Scope changes relative to v1.0 are discussed in Section 3. One major element of the upgrade plan not included in v1.0 was the Commissioning Plan of the Recycler Ring. This plan is now included in this v2.0 document and the plan is briefly outlined in Section 3. The resource-loaded schedule and cost and schedule summaries are discussed in Section 4. In Section 5, the projection for luminosity performance is presented. The upcoming DOE review web-site (in preparation) is at Ref. 7.

The upgrade program consists of sub-projects which aim at increasing the antiproton production rate by increasing the proton flux on the antiproton production target, improve collection, stacking and cooling abilities in the antiproton source and the Recycler, and upgrade the Tevatron to perform with higher intensities of protons and antiprotons. The upgrades are staged in five phases from now through 2007, the start of each phase being associated with the completion of a major element of the upgrade plan.

1.1 Performance Goals

In v1.0 of the upgrade plan of July 2003, an evaluation of the performance and schedule for the upgrades led to the integrated luminosity "design projection" (defined as using reasonable performance parameters and requiring reasonable improvements over past performance, but not including scheduling contingency) and "base projection" (using conservative parameters and including scheduling contingency) starting from FY 2003 through the completion of the upgrades. We continue to describe the performance goals in terms of the *base* and *design* projections introduced in v1.0.

The instantaneous luminosity at each experiment is given by the formula

$$L = \frac{3\gamma f_o B}{\beta^*}\frac{N_p}{\varepsilon_p}\frac{N_{\bar{p}}}{(1+\varepsilon_{\bar{p}}/\varepsilon_p)}H$$

where γ is the relativistic energy factor, f_o is the revolution frequency, N_p and $N_{\bar{p}}$ are the numbers of protons and antiprotons per bunch and B is the number of bunches of each. β^* is the beta function at the center of the interaction region, and ε_p and $\varepsilon_{\bar{p}}$ are the proton and antiproton 95 %, normalized, transverse emittances. H is the hourglass form-factor due to the bunch lengths.

While the luminosity depends on the transverse emittances explicitly and on the longitudinal emittance through the hourglass form-factor, the most direct way to increase the luminosity is to increase the proton and antiproton bunch intensities. However, the number of protons per bunch used in the Tevatron is already a factor of ten higher than the number of antiprotons and the term N_p/ε_p (the proton brightness) is to be constrained by the maximum tolerable antiproton beam-beam tune shift that it causes. Therefore, the strategy for Run II upgrade is to increase the luminosity primarily by increasing the number of antiprotons and using them efficiently in the collider operations.

The key parameters in the luminosity formula are listed in Table 1.1, along with parameters defining the rate of antiproton production. The table compares the performance values for present operation with those projected for the completion of the upgrade program. It should be noted that the parameters quoted are for typical performance. The Tevatron achieved a record peak luminosity of $52\text{x}10^{30}$ $cm^{-2}s^{-1}$ in December 2003. The record integrated luminosity per week reached 11.3 pb^{-1}.

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Parameter	Units	12/31/03-1/15/04	Run II *Design*
Peak Luminosity	$x10^{30}cm^{-2}sec^{-1}$	38	275
Store hours per week		112	99
Store Duration	hr	24	15
Integrated Luminosity	pb^{-1}/wk	7.7	47
Number of Bunches		36	36
Protons/bunch	$x10^9$	223	270
Antiprotons/bunch	$x10^9$	24	127
β*	Cm	40	35
Proton Transverse Emittance (at collision)	π-mm-mrad	28	25
Antiproton Transverse Emittance (at collision)	π-mm-mrad	12	15
Hourglass Form Factor		0.65	0.65
Pbar Transmission Efficiency to low beta	%	75	80
Stack Used	$x10^{10}$	113	569
Avg. Antiproton stacking Rate	$x10^{10}$ /hr	4.7	39

Table 1.1: Comparison of key luminosity performance parameters for Jan 2004, and the Run II *design* goals. The peak luminosity record to-date, set on December 29, 2003, is $52x10^{30}$ $cm^{-2}s^{-1}$ and the weekly integrated luminosity record to-date is 11.3 pb^{-1}.

The performance parameters and the *base* and *design* luminosity projections for the upgrade program are presented in more detail in Section 5.

1.2 Project Organization

The Run II upgrade program consists of two categories of subprojects – Luminosity Upgrades and Maintenance and Reliability Upgrades, and is closely integrated with Run II Operations. The upgrade projects include all planned upgrades to the accelerator complex in support of Run II. The Maintenance and Reliability projects address the concerns raised in a vulnerability study which identified component failures that would result in significant down-time for the complex and loss of integrated luminosity for the experiments (Refs. 7 and 8). Run II Operations includes operation of the complex along with immediate maintenance and operational improvements. The Run II organization and line management structure is illustrated in Fig. 1.1.

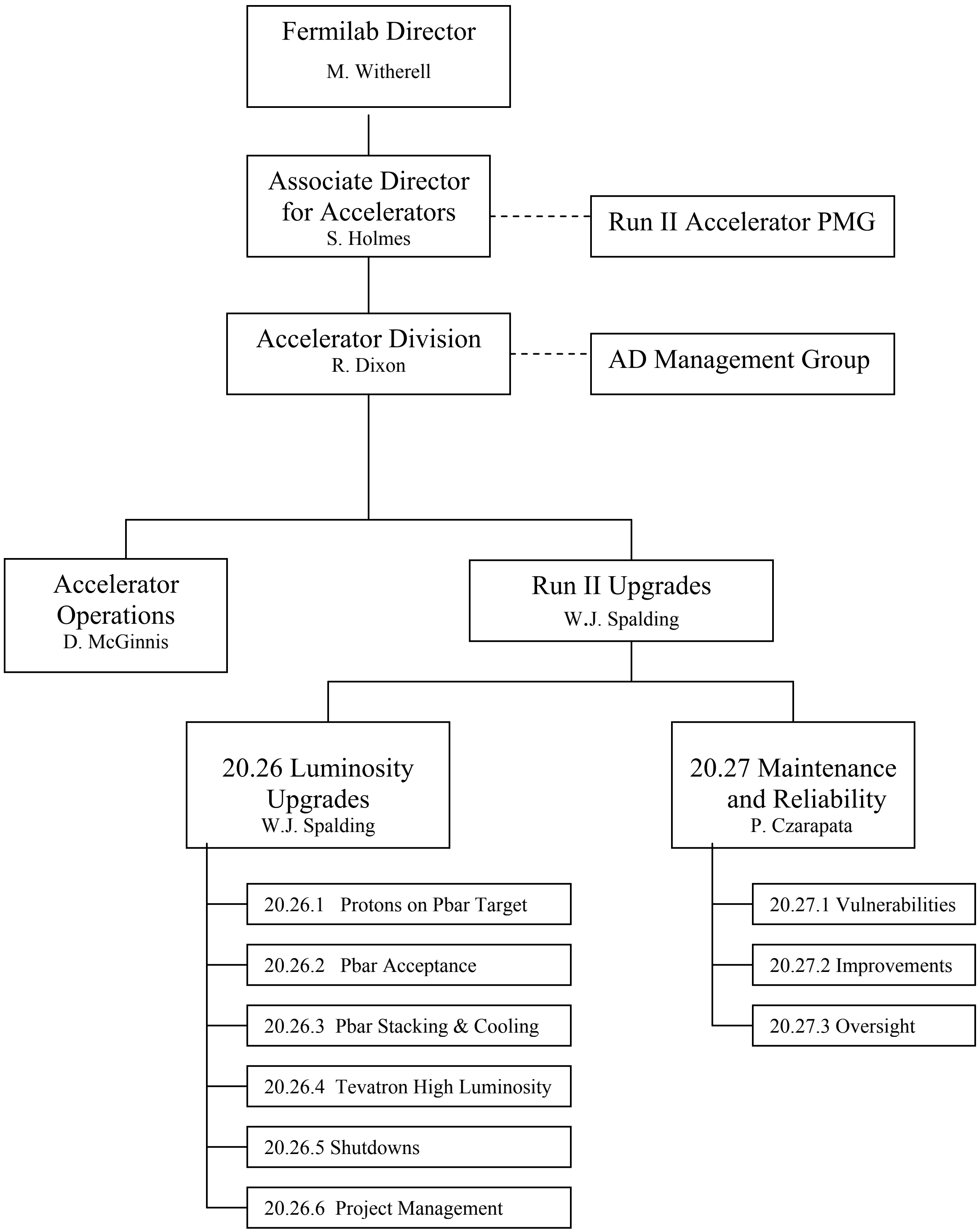


Fig. 1.1. Run II Organization.

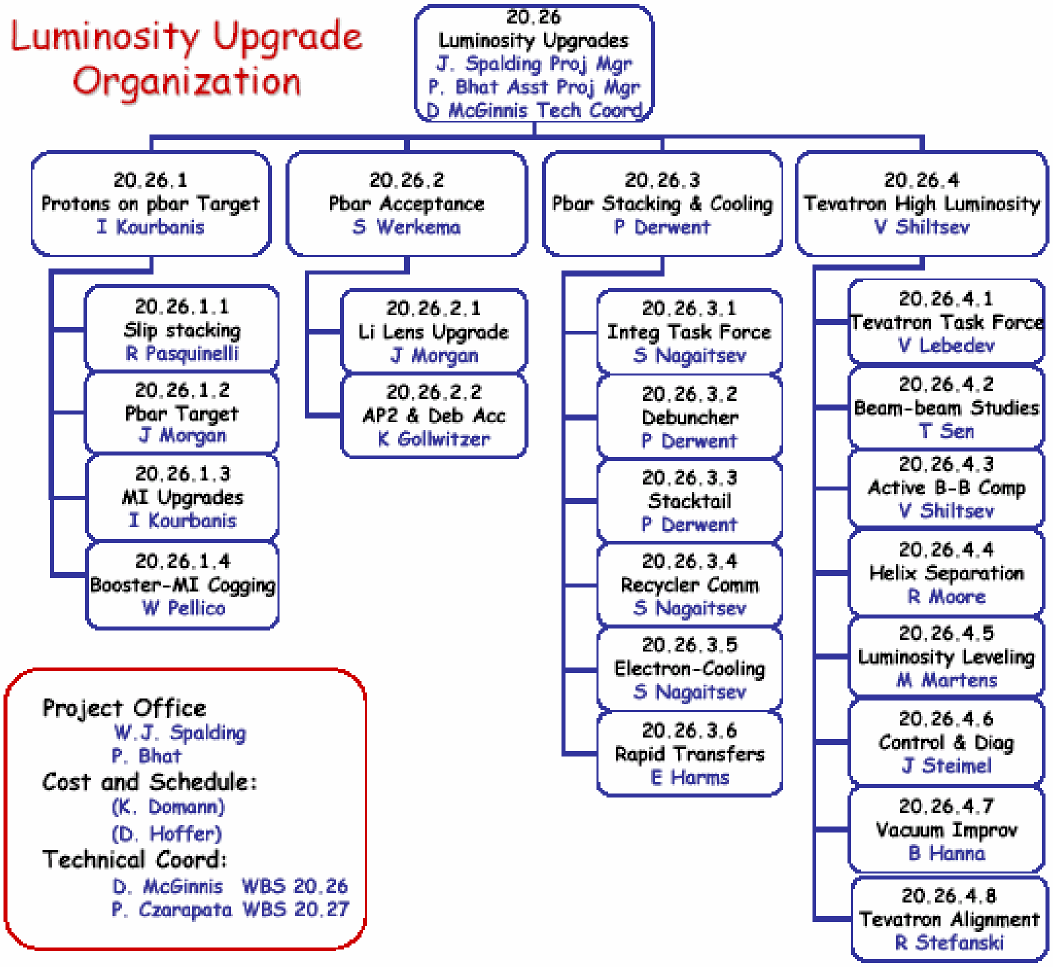


Fig. 1.2. Run II Luminosity Upgrade Organization

The Run II Luminosity Upgrade Program consists of a set of subprojects for upgrades in each of the accelerators in the complex, consolidated into a single coherent work plan. The program is managed from the Accelerator Division Headquarters Office with a project manager, an assistant project manager and a technical coordinator. The Run II luminosity upgrades organization down to Level 3 is shown in Fig. 1.2.

The luminosity upgrades are organized in four main branches, considered as Level 2 within the project, with a leader for each branch. Within the branches, each subproject has a leader. In many cases these Level 2 and Level 3 project leaders are themselves department heads or group leaders in the Accelerator Division line management, so this project organization is integrated with the department organization.

While the Run II upgrades include all upgrades planned with a long-term view, there are many operational improvements in both reliability and performance, which occur along with accelerator operations. These improvements are developed directly from operational experience gained, and can not be explicitly captured under a WBS. As described in

Section 4 while discussing labor and efforts, the resources for these improvements are treated as a steady-state need based on recent operational experience.

The principal elements of the Luminosity upgrade plan are outlined in the next sub-section.

1.3 Principal Elements of the Upgrade Plan

The central strategy for the Run II luminosity upgrade is to produce, transport, cool and store more antiprotons and use them efficiently in collider stores in the Tevatron. The upgrade project is organized into four main sub-projects based on the four primary tasks at hand:

1. Protons on (antiproton production) target
- increase antiproton production rates by increasing proton flux on the antiproton production target

2. Antiproton Acceptance
- increase the collection efficiency of produced antiprotons and increase the aperture in the transfer beamline (AP2) and the Debuncher

3. Antiproton Stacking & Cooling
- improve the stacking rate and stack size for antiprotons and the transfers between the Accumulator and the Recycler, so that more antiprotons can be accumulated (stacked)

4. Tevatron Upgrades
- upgrade the Tevatron for operation at higher bunch intensities

The sub-projects are implemented in collider operations in five operating phases. We are currently in Phase 1. The start of each future phase marks successful completion of a major piece of the upgrade project that will allow a significant increase in luminosity. These operating phases are summarized below:

- *Phase 1 – Present:* This first phase of upgrades includes several improvements throughout the accelerator complex, with component realignment in machines, upgrades to the Antiproton Source to allow reduced cycle time, completion of damper systems in the Main Injector and improvement to the helical orbits in the Tevatron. Operational improvements will focus on increasing the proton and antiproton transfer efficiency and reducing the emittance growth during shot set-up.
- *Phase 2 – December 2004:* Slip stacking becomes operational and the first part of the antiproton acceptance upgrade to support higher proton flux on target will have been completed.
- *Phase 3 – June 2005:* Recycler and Electron Cooling are integrated into operation. Antiprotons are loaded from the Recycler, rather than from the Accumulator for Collider stores.

- *Phase 4 – December 2005:* Completion of the upgrade of the Accumulator stacktail cooling system allows significantly higher antiproton stacking rates. Small antiproton stacks are transferred to the Recycler every half hour.

- *Phase 5 – February 2007:* Tevatron helix improvements and beam-beam effect mitigation in the Tevatron completed. All upgrades including AP2 and Debuncher acceptance upgrades will have been completed.

The AP2 and Debuncher acceptance will be increased throughout the period of these upgrades, with major realignment or replacement of components occurring during each of the scheduled shutdowns. All major component replacements will be completed by the end of the 2006 shutdown.

Throughout these upgrades, beam studies are required to develop the upgrades themselves, and this is taken into account in the luminosity projection discussed in Section 5. On completion of Phase 5 this study time will no longer be needed, although studies to maintain optimal operation of the complex will continue.

1.4 Principal Elements of Run II Operations

The principal elements of the ongoing support for operations are defined within the laboratory's WBS. Included are routine maintenance activities required to keep accelerator equipment in operational condition, and incremental improvements aimed at improving reliability and maximizing performance of the accelerator complex as configured at any given time. Examples of activities supported in this area include:

- Maintenance of all electrical and mechanical devices/systems in the accelerator complex.
- Minor projects aimed at improved reliability and performance of operating systems.
- Maintenance and improvements to RF, instrumentation, and controls systems.
- Materials purchases of cryogens required for Tevatron operations.
- Control room support for accelerator operations.
- Accelerator physics support for operations.

1.5 Principal Elements of the Maintenance and Reliability Upgrades

Major vulnerabilities within the accelerator complex were identified in a study completed in the summer of 2002 (Ref. 8). These are components or component classes identified as having the potential for interrupting operations within the accelerator complex for more than 3 months in the event of failure. The list of 44 components and/or component classes so identified was subsequently evaluated and prioritized to highlight several items as requiring immediate attention.

Since completion of the vulnerabilities report, the situation within the upstream end of the linac (the drift tube portion) has been aggressively pursued. A task force was established to develop both short and long term strategies. Possible long term responses range from reestablishment of the current vendor as a reliable source of tubes, to the procurement of a new, klystron powered, drift tube linac. At the present time, 3 spare tubes are available and the vendor is producing 1-2 tubes per month.

One of the leading causes of lost stores in the Tevatron was identified to be due to problems with Voltage to Frequency Converters. Most of the upgrade planned for their monitoring has been completed and the remaining is phased in between now and the next shutdown. Main Injector (MI) and beamline transformers have been either ordered or specified. Ceramic beam-tubes for the MI kickers are being procured. In case of kicker pre-fires, additional collimators were added to shield experiments in the event of a pre-fire. Resonant charging systems were evaluated and a cost/benefit position developed. A large number of deteriorated magnet stands in the Tevatron were replaced during the 2003 shutdown.

Recently, failure of CDF Tokyo pots' controller caused it to move into the beam in the Tevatron resulting in a 16 house quench and several days of down time. The failure mode has now been understood. A Tevatron abort system task force has been assembled to specify upgrades to the abort logic that would significantly reduce such risks in future.

2. Upgrade Projects: Technical Progress

We discuss here the sub-project goals and technical progress made since July 2003 on a number of fronts. Also, a number of technical reviews of sub-projects have been held to help make scope and design decisions, evaluate technical progress and verify that milestones have been met. We discuss these technical reviews, their outcome and the follow-up actions taken as a result.

2.1 Protons on Target

(WBS 26.1)

The primary goal of this branch of the project is to double the antiproton production rate by doubling the proton intensity on the production target and to make necessary upgrades to the target station to take full advantage of the increased incident proton flux. Other upgrades in the Main Injector that are aimed at improving the Main Injector performance are also included under this WBS.

SLIP STACKING IN THE MAIN INJECTOR

The doubling of proton intensity for antiproton production is to be accomplished by a technique called "slip stacking," which merges two batches of protons from the Booster. There has been excellent progress. Slip stacking has now been demonstrated up-to total intensities of 6E12 protons and the stacked proton beam has been accelerated to 120 GeV in the Main Injector with 93% efficiency. The *design* goal is to reach proton intensities of 8E12 protons with specific requirements that bunch length be less than 1.5 nsec and transverse emittance less than 25 π mm-mrad. Despite the large intensities that have been achieved so far, for slip stacking to be useful, it is necessary to minimize the longitudinal emittance growth that is now seen from recapture to flat-top. Beam studies aimed at achieving smaller longitudinal emittance both during recapture and acceleration are continuing. Further progress on this project requires upgrades to the RF system that enables compensation of beam-loading effects. Better amplitude and phase control of the 53 MHz RF cavities are also required during the RF manipulations at recapture. Longitudinal bunch-by-bunch dampers are also being commissioned.

A technical review was held in August 2003 to review the beam studies and the design of the beam-loading compensation system. The review committee approved the proposed hardware design and recommended the purchase of additional power amplifiers and associated hardware required to implement the beam-loading compensation. Purchase orders were placed ahead of schedule in August 2003. One complete RF station has been upgraded with eight solid state amplifiers, available as spares, for test purposes. A new medium level vector control of RF voltages is being developed. This is expected to provide a factor of 4-5 better accuracy for setting RF voltages on cavities.

UPGRADES TO THE ANTIPROTON PRODUCTION TARGET STATION

Two upgrades are intended to reduce damage to the antiproton target station with the increased flux delivered by slip stacking. They are: (1) use of target materials that are more resilient to local heating caused by beam and (2) sweeping of proton beam across the target to reduce local heating. Stainless Steel 304 target with graphite skin has been identified as having excellent longevity and superior resiliency than the previously used targets. The beam-sweeping system has been partly commissioned, but it is unnecessary at least until the slip stacking becomes operational. Therefore, the priority on the beam-sweeping system has been lowered and the schedule has been relaxed.

MAIN INJECTOR UPGRADES

<u>2.5 MHz Acceleration in the Main Injector:</u>

The 2.5 MHz acceleration through transition in MI followed by a bunch rotation at a front porch at 27 GeV was proposed in the Recycler Technical Design Report (Ref. 10) as an alternative scheme for antiproton coalescing. This new scheme is expected to reduce the

longitudinal emittance blow-up to the order of 50% or less compared with the 100-140% blow-up with the current antiproton coalescing. This implies that the scheme could yield significant improvements in Run II operations. In particular, reduced longitudinal emittance would result in a longer 150 GeV lifetime in the Tevatron. The antiproton beam size at injection into the Tevatron will be reduced, and less transverse emittance dilution in the Tevatron is also likely.

A technical review was held in September 2003, to evaluate the project status and to better understand the project scope and prioritize accordingly. The committee, after reviewing the presented beam study results and simulation studies, was convinced that the 2.5 MHz antiproton acceleration provides an operation scenario where longitudinal emittance is reduced and beam loss is eliminated and that it can potentially provide up-to 20% increase in luminosity. Since the time of the review, final specifications for the 2.5/53 MHz beam-loading compensation have been completed. Beam studies aimed at commissioning the beam-loading compensation and optimization of the acceleration parameters are underway. So far, protons have been successfully accelerated to 150 GeV with the 2.5 MHz scheme with 85% efficiency.

The 2.5 MHz acceleration scheme is more crucial for antiprotons coming from the Recycler due to the larger longitudinal emittances (1.5 eV-sec or larger) and will provide added performance margin for electron cooling.

<u>Main Injector Dampers:</u>

Dampers for both longitudinal and transverse oscillations have been installed in the Main Injector and have been tested on coalescing cycles. As a result of the use of longitudinal dampers and 53 MHz feed-forward beam-loading compensation, the longitudinal emittance of better than 2.5 eV-sec at 150 GeV has been achieved for coalesced proton bunches injected into the Tevatron for collider stores in recent shots. The longitudinal dampers will be necessary to reduce bunch length on the antiproton production target and bunch-to-bunch jitter with slip-stacked protons on target.

BOOSTER-MAIN INJECTOR COGGING

In order to sequentially transfer two Booster batches for slip stacking in the Main Injector, the Booster and the Main Injector have to be synchronized and their RF buckets properly aligned. Cogging has been shown to work in the Booster with the resolution of a couple of buckets. The plan is to improve the resolution to within a bucket. Booster to Main Injector multi-batch transfers with cogging are to be tested in the near future.

2.2 Antiproton Acceptance

(WBS 26.2)

It is important to efficiently transport, stack and store the produced antiprotons. This project is aimed at increasing the acceptance of antiprotons and focuses on the elements that are immediately downstream of the production target - the lithium collection lens, the AP2 beamline and the Debuncher ring.

THE LITHIUM LENS

The lithium lens is the first component downstream of the production target and has significant impact on the acceptance of the antiproton source. The number of antiprotons collected at the upstream end of the AP2 beamline increases with the magnetic field gradient at which the lens is operated. The lens currently in use was originally designed for operation at a gradient of 1000 T/m, but is operated at 750 T/m to increase its operational reliability and longevity. Operating at the higher design gradient is expected to provide 10-15% increase in the antiproton acceptance. It is planned, therefore, to build new lenses with better design and operate at higher magnetic gradient. The improved design is based on much improved mechanical and thermal modeling and the technology of diffusion bonding. The first prototype lens using diffusion-bonded Titanium body has been built and is on track for completing tests by the middle of February 2004. High gradient tests of the lens are also in progress.

AP2 AND DEBUNCHER ACCEPTANCE

The AP2 beamline transports the antiprotons from the target and lithium lens to the Debuncher ring. The goal of this subproject is to locate the limiting apertures and eliminate them through realignment, relocation, improvements in beam steering, or by rebuilding components. The procedures to identify aperture limitations include (a) assembling and using of documentation and drawings, (b) performing optical survey and alignment, and (c) developing and using beam-based alignment procedures. Compilation of documents and drawings is nearly complete. Extensive optical survey of the elements has been conducted during the 2003 shutdown and the data are being examined. Crude tools to perform beam-based alignment exist and they are being refined. One of the RF cavities (DRF3) in the Debuncher, recognized as limiting aperture, has been moved from a high dispersion location to a zero dispersion location. (Initial plans were to relocate this in the summer 2004 shutdown.) The aperture in the Debuncher has improved by 12 % in the horizontal plane and 4% in the vertical plane since the relocation, which is considered as due to a combination of the cavity move and machine/orbit tuning. Lawrence Berkeley National Laboratory (LBNL) is a collaborator on this project and a memorandum of understanding between the two labs is being signed.

In order to help improve local orbit control in the Debuncher, motorized stands were installed for ten quadrupoles during the shutdown. Twenty more will be installed in due course. Beam position monitors have been commissioned and the software, though not complete, is sufficiently advanced to provide useful data during studies and operations.

2.3 Antiproton Stacking and Cooling

(WBS 26.3)

This branch of the upgrade project encompasses stacking and cooling of antiprotons both in the antiproton source and the Recycler. The stochastic cooling systems in the Debuncher and the Accumulator rings are being upgraded to achieve more than three times the current peak stacking rate. To sustain such high rates for several hours and build up large stacks of antiprotons (600×10^{10} total), partial stacks are to be transferred periodically from the Accumulator to the Recycler. The antiprotons are stacked and stored in the Recycler until used in a collider shot. The Recycler will use both stochastic cooling and electron cooling systems to maintain such large stacks with desired beam properties.

DEBUNCHER AND ACCUMULATOR STACKING AND COOLING

The cooling systems in the Debuncher and Accumulator rings will be upgraded to allow a higher stacking rate. These upgrades will be implemented in two phases.

In Operating Phase 1, the Debuncher system will be improved by lowering the zero stack cycle time to about 1.7 seconds from the present 2.4 seconds. (The repetition rate will later be increased to 2.0 seconds when the Main Injector supports slip stacking and NUMI operation.) This can be accomplished by reducing the Debuncher momentum cooling notch filter dispersion by 33%. A 42% reduction in the cooling time (~0.79 sec to ~0.46 sec) and a 18% reduction in the 95% asymptotic width have been observed due to improvements made over the past year. At 2 seconds (target time for transfer in Run II upgrade scenarios), the 95% width is 7 MeV/c, close to the Run II goal of 6 MeV/c. The next iteration of improvements with optical notch filters, that are a factor of 3-4 better than the Bulk Acoustic Wave filters now used, is aimed at reaching the goal.

The stacktail cooling system in the Accumulator will be upgraded for Operating Phase 3.

A review of the stacktail betatron cooling was held to decide whether a stacktail betatron cooling system is required. The calculations presented at the review (Ref. 11) suggest that it is not needed. However, the committee also pointed out that the calculations suffer from not including an estimate of the heating of the longitudinal cooling systems. The core cooling system alone would have sufficient margin if the cooling rate degraded by a factor of 2, including all heating terms. This would still result in a 10π mm-mrad (95%, normalized) emittance. Therefore, it has been decided that the core cooling system is likely to achieve this goal, making a stacktail system unnecessary.

The stacktail momentum cooling system design is being discussed and engineering efforts are being examined. The plan is to replace half of the 2-4 GHz tanks with new 4-6 GHz tanks in the stacktail cooling system to significantly improve the system capability at high stacking rates. Some of the hardware necessary for this upgrade, such as the Traveling Wave Tube (TWT) devices and their power supplies are standard items and have a long lead-time for procurement. These TWTs are also used in the cooling system of the Debuncher. A partial installment of twenty four TWTs and power supplies has been ordered.

RECYCLER RING STACKING AND COOLING

The Recycler Ring will play a key role in building up very large stacks of antiprotons for use in collider stores. The full utilization of the stacktail cooling upgrade in the Accumulator requires that large stacks be stored in the Recycler Ring using Electron-Cooling, and that partial-stacks of antiprotons be transferred from the Accumulator to the Recycler every 30 minutes in optimized transfers called “Rapid Transfers”. In order to cool the very large stacks anticipated, the Recycler will use both stochastic and electron cooling.

The vacuum problems that interrupted the commissioning of the Recycler in early 2003, have been successfully resolved during the 2003 shutdown and excellent progress has been made in its commissioning.

<u>Recycler vacuum work during the 2003 Shutdown:</u>
The emittance growth due to residual gas Coulomb scattering was identified as the most significant obstacle on our way toward bringing the Recycler into operations. The Recycler department developed a detailed plan for the 10-week shutdown in 2003. This plan was reviewed and approved by a committee of internal and external vacuum and beam experts, in August 2003. The main ingredients of the plan were to (1) complete the installation of bake-out heaters to provide bake-out capability for the entire ring, (2) bake the entire Recycler ring and (3) improve vacuum instrumentation and diagnostics in order to better understand the vacuum. All of these goals have been achieved and spectacular results have been obtained.

<u>Recycler Performance Parameters:</u>
Criteria for the Recycler performance during FY2004 and beyond have been developed, documented and reviewed. The performance goals and parameters include those for the Recycler subsystems (e.g. cooling, vacuum, etc.) and beam characteristics such as lifetime, emittance growth rates and final acceptable values for longitudinal and transverse emittances at specified beam intensities as well as Accumulator-to-Recycler transfer and stacking efficiencies. The measurement techniques used to determine performance parameters have also been outlined. These criteria are shown in Section 3.2. Some of the criteria have already been met.

Transfers of small stacks of antiprotons from the Accumulator to the Recycler via the Main Injector, tests of stacking, stochastic cooling and storage in the Recycler as well as efficient extraction are being methodically tested as part of the first stages of commissioning.

The Recycler Commissioning Plan is described in Section 3.2 under scope changes and detailed in a technical note that will be available through the review web page.

ELECTRON COOLING

The implementation of electron cooling will allow very large antiproton stacks accumulated in the Recycler Ring to be transferred to the Tevatron with small longitudinal emittance. The initial phase of the project is well advanced. This includes an R&D program at the Wide Band Laboratory for the development of a system to produce an electron beam with the specific characteristics required. The R&D project is on schedule. A milestone of 500 mA beam current was achieved on Dec 30, 2003. The construction of a building in MI 31 for housing the Pelletron is expected to be completed by April 2004, at which time the electron cooling system will be relocated to the Recycler. The system will be commissioned in the Recycler to begin cooling the antiproton beam in early 2005.

RAPID TRANSFERS

At present, small stacks are transferred from the Accumulator to the Recycler periodically to support commissioning of the Recycler Ring. The transfers require manual tune-up of the transfer beam lines and typically interrupt stacking for about one hour. Once electron cooling is implemented in the Recycler, and the Accumulator Upgrade has been completed, it will be necessary to transfer a partial-stack every half hour. A transfer time of less than one minute (during which stacking in the antiproton source is interrupted) is to be achieved by automating the transfer process, which will require upgrades to the beam line instrumentation, improvements to the power supply regulation, and feedback from the Main Injector damper system. Progress is being made on all these fronts.

2.4 Tevatron High Luminosity

(WBS 26.4)

The first three branches of the upgrade plan will result in a significant increase in antiproton bunch intensities in the Tevatron. In addition, we intend a modest increase in proton bunch intensity. The fourth branch includes upgrades to the Tevatron itself to optimize performance with these increased intensities.

TEVATRON TASK FORCE

The Tevatron task force, which has a large contingent of members from the integration department, had concluded, after careful studies, that the strong coupling between vertical and horizontal motions seen in the Tevatron was due to skew-quadrupole fields in dipoles as a result of coil displacement. The strong coupling had resulted in the necessity for running some of the correctors close to their limits. These were fixed in the 2003 shutdown (as described later under "Tevatron Alignment") with excellent results.

The P1 line optics has been redesigned to match the vertical dispersion in the Tevatron. The correction requires rolling 4 quads (~2 –3 deg.) in the P1 line. This is expected to be performed as the Tevatron schedule allows.

Tevatron optics measurements performed at injection, top energy and low-beta showed betatron mismatches ($\Delta\beta/\beta \sim$ 10-20%). The injection mismatch was fixed before the shutdown. Fixes for top energy and at low-beta will be done as and when possible. Efforts are underway to develop data acquisition software to make high precision optics measurements and some of this work is done in collaboration with Argonne National Laboratory.

The task force continues to work on Tevatron lattice modeling, luminosity modeling and beam-beam simulations.

ACTIVE BEAM-BEAM COMPENSATION

Two approaches to active beam-beam compensation were included in v1.0 of the plan – (1) using an electron lens with beam aligned on the antiproton beam to provide bunch-by-bunch tune corrections and (2) using current-carrying wires to compensate for long range beam-beam interactions.

<u>Electron Lens</u>:

An electron lens was installed in the Tevatron in 2001 with the intent of testing its use for beam-beam compensation. However, it has been primarily used, as an abort gap cleaner. Some preliminary beam studies carried out last year have yielded promising results for bunch-by-bunch tune corrections. The construction of a second Tevatron electron lens was begun by the middle of 2003. The project is to be reviewed in May 2004 and the second electron lens will be installed in the Tevatron in October 2004. Instrumentation for tune and position measurements is being improved to help commission and use the electron lens for active beam-beam compensation.

<u>Wire-based active beam-beam compensation:</u>

The concept of wire-based compensation to mitigate long-range beam-beam effects has been proposed for the LHC and was recommended to be investigated for use in the Tevatron by the DOE review committee in October 2002. Some simulation work had been done in this regard. A review was arranged to assess the potential benefits of wire-based beam-beam compensation and status of studies and to help make decision on initiating R&D for a proto-type wire test station, with the expectation that the R&D would be further reviewed before a decision on a production system is made. The committee unanimously agreed that "the application of wire-based beam-beam compensation to the Tevatron is complicated when compared to the LHC, where it *appears*, at least, to be relatively straight-forward." Given the high complexity, it was suggested that a clear set of goals and simple models to explain how the system is supposed to work be developed. It was deemed that committing to any design and engineering work was pre-mature. It was recommended that the project continue as a beam physics study to systematically characterize the beam-beam long range fields and to investigate devices/strategies for compensation, giving priority to the most important effects. Therefore, the wire-based compensation project has been dropped from the scope of the upgrade projects. Simulation studies and collaborative work with CERN LHC will continue, and will be reviewed in spring 2004.

INCREASED HELIX SEPARATION

Long-range beam-beam interactions between the proton and antiproton bunches can lead to significant tune shifts. In general these tune shifts decrease as the second power of the orbit separation, so an increase in this separation can significantly reduce the beam-beam effects. The plan is to improve the orbits and helix separation in a series of steps, including optimization of the present system, the installation of polarity switches to allow more flexibility and upgrades to the separator system. Two upgrades have been under consideration - upgrade to the existing separators to allow operation at higher voltages and adding new separators, including longer separators at the interaction regions.

A one day review looked at the current status of helix operations in the Tevatron and proposals to improve the helix scheme with the existing separators and with additional longer separators. The committee endorsed plans to (a) build polarity switches for all separators so that antiproton helix can be tuned with reverse protons, (b) install six additional separators in the arcs and (c) explore helix schemes to optimize separation. The committee recommended that the project team not pursue building of longer separators for the interaction regions, but explore a fewer number of shorter separators, instead. A number of other recommendations were made to improve separator conditioning and performance.

Based on the committee recommendations, six additional separators of the present design and polarity switches for all separators are in the process of being built and installed. These separators are expected to provide 20% more separation of the proton and antiproton helices than present in the arcs and 10% more separation in the first parasitic crossings near the interaction regions. Operation of the existing and additional separators at higher voltages will be explored to provide additional increase in separation. It was decided not to build longer separators for the interaction regions, but to include an option in the project plan to build four shorter separators which would provide ~14-17% increase in separation. This option will be exercised depending on the outcome of the voltage studies for the existing separators.

CONTROLS & DIAGNOSTICS

In order to improve the controls & diagnostics in the Tevatron, several tasks have been identified in the plan.

Tevatron BPM System:

A joint Accelerator and Computing Division team was formed in August 2003 to design and implement the Tevatron Beam Position Monitor (BPM) upgrade. The project team had successful reviews of the requirements document and the technology choices for BPM signal processing. The requirements, updated based on the recommendations from a preliminary review in June 2003 and the DOE review in July 2003, were reviewed and approved in September 2003 to proceed to the design phase. A review of the technology choice for signal processing was conducted in December 2003. The committee endorsed the choice made by the project team of purchasing Digital Receiver boards (to be modified as per our specification) from the EchoTek company. The committee agreed with the project team that the proposed commercial solution was the only viable option to meet the project completion date goal of October 1, 2004. EchoTek is also the supplier of signal processing boards for the recent Recycler BPM upgrade which has worked out well. The committee, however, recommended that the purchase be contingent upon the project team instrumenting one BPM system completely and adequately demonstrating the performance of the system in terms of the position accuracy for closed orbit measurement of protons in the Tevatron.

As per the recommendation of the committee, a prototype station is partly commissioned using the EchoTek digital receiver board (a spare from the Recycler BPM project). The preliminary beam data from the station taken during a recent store indicate that a closed orbit measurement resolution of 7 microns can be achieved. After successful demonstration of the electronic processing and that the under-sampling of the signal and the frequency domain analysis technique are viable approaches to meet the requirements, the project will proceed to procurement of the modified EchoTek boards and detailed technical design. The project is moving forward and the initial installation of the new system is expected to begin in summer 2004.

Tevatron Ionization Profile Monitor:

An Ionization Profile Monitor (IPM) is being built for installation in the Tevatron in the 2004 shutdown. The goal of the Tevatron IPM project is to be able to measure injection mismatch and emittance evolution on the ramp. The detector design and associated technical issues were reviewed in order to make decision on whether to proceed with the project or not. The schedule for the project was a major concern. The committee strongly felt that the diagnostics from the IPM would be very valuable in the Tevatron and the project should indeed be expedited in order to maximize the benefits to the Run II operations.

The schedule and resources for the project have been re-worked with a new completion date of August 2004. Since the conceptual design passed the internal review, the project is now in a technical design and production phase. The long-lead time components such as the magnets required to focus the ionization electrons have been identified and prioritized. The magnets have been specified and ordered from an outside firm. Development of the electronics is underway. The design work on time-critical elements such as magnet stands and cabling will start shortly.

Other Tevatron Controls & Diagnostics Projects:
The 1.7 GHz Schottky hardware has been commissioned. Development of controls and data acquisition software continues. The Tevatron transverse injection dampers are ready to be commissioned. Other diagnostic devices such as the tune tracker, head-tail monitor, and abort gap monitor, are making good progress.

TEVATRON ALIGNMENT

Prior to the 2003 shutdown, the Tevatron Alignment Task Force put together a set of measurements of magnet positions in the Tevatron. This was the most complete set of measurements available since the early days of the machine. Also, at this time, the Technical Division detected systematic downward shifts in Tevatron dipole cryostats. With this information, the Tevatron Task Force studied the strong steering corrections, and transverse couplings observed in the Tevatron. These studies combined with new alignment data, and measurements regarding dipole cryostat movements accurately explained the machine's behavior, and provided a believable model for Tevatron optics. This work indicated that improved machine performance based on improved apertures, a reduction in corrector currents, and better control of transverse coupling, required significant magnet realignment and repairs in the tunnel. A proposal to implement corrective action for these problems was developed and after several reviews provided a plan for alignment work during the 2003 shutdown.

The work consisted of many parts: A new alignment network (TevNet) was implemented in the Tevatron to improve alignment precision and to simplify the process of alignment, dipole cryostats were re-shimmed to correct for cryostat movement, "rolled" magnets were unrolled to reduce corrector magnet currents, deteriorated dipole magnet stands were replaced to improve our ability to align magnets, and real-time motion sensors were installed on Tevatron components to monitor magnet movement remotely. In addition, the Tevatron Department took on the task of correcting two long-standing problems at the Interaction Regions (IRs): A correction of about 6 mm misalignment of the low beta quads at D0, and a vertical displacement of the CDF interaction point by about 4.5 mm.

This combined effort included physicists and technicians from the Accelerator, Computing, Particle Physics and Technical Divisions. CDF and D0 experimenters were involved in measuring all magnet rolls, and an alignment crew from Stanford Linear Accelerator Center (SLAC) participated in the survey effort. As a result of this work, the Tevatron has seen significant improvement in operations. The correctors are running at weaker currents, orbits are smoother at all stages, and couplings are smaller compared to before the shutdown. The Tevatron set a new luminosity record of 52x 10^{30} cm^{-2} sec^{-1} in the post-shutdown operations.

This alignment work will be continued during future shutdowns, although the efforts are expected to be much smaller in magnitude than was necessary in 2003.

3. Scope Changes from V1.0

As described in Section 4, milestones are used to (a) mark the completion of major tasks or sub-projects, (b) track progress, (c) trigger reviews when scope decisions are to be made, (d) transition from requirements to system design or from design to production. In particular, there were several milestones since July 2003 for scope decision points.

Formal reviews are held for scope evaluation, for approval of system requirements, system design and major installation/repair activities. Most of the technical reviews include experts from outside the laboratory. The documentation, reports and management decisions from the eleven reviews held since July 2003 are available by following the "Upgrade-related Reviews" link at Ref. 11. The highlights of the reviews were included while discussing the technical progress in the previous Section.

3.1 Scope Decisions

As a result of technical reviews and closely tracking the progress of various sub-projects, several scope changes have been made in v2.0 in comparison to v1.0. We summarize the changes, below.

WBS 26.1.2.2 BEAM-SWEEPING ON ANTIPROTON PRODUCTION TARGET
(Priority lowered)

<u>WBS Description of affected tasks:</u>
The beam-sweeping system will move the proton beam across the target during the beam pulse to distribute the heating. The downstream sweeping magnet is required to restore proper steering for the secondary beam.

<u>Description of Change:</u>
The task completion date for the beam-sweeping system has been moved from 1/21/04 to 8/25/04. The system will not be required, until slip stacking of protons in the Main Injector becomes operational and nearly doubles the proton intensity on the pbar production target. Also, even at double the proton intensity on the target, beam-sweeping is expected to be beneficial for target longevity but not an absolute necessity. The priority for this project has therefore been lowered and the schedule relaxed.

WBS 26.3.3.2 STACKTAIL BETATRON COOLING
(Scope reduction)

<u>WBS Description of affected tasks:</u>
Design and Install a new stacktail betatron system to give additional transverse cooling during the stacking process. At the time it was not clear whether the system would be required.

Description of Change:
After a review of the calculations, it has been decided that the core cooling system is likely to achieve the transverse emittance goal, making a stacktail system for transverse cooling unnecessary. It has been recommended, however, that the calculations be extended to include betatron heating by the stacktail longitudinal system to confirm this conclusion. The calculations require input from measurements made with beam. At the time of the aforesaid review, it was also apparent that there is no point in proceeding with the current design since any improvement obtained would be marginal. As a result, the betatron system will be dropped from the project scope, but further studies and calculations will continue.

WBS 26.4.3.2 WIRE-BASED COMPENSATION OF BEAM-BEAM EFFECTS
(Scope reduction)

WBS Description of affected tasks:
Investigate the use of pulsed wires for beam-beam tune-shift compensation (as proposed for LHC). Initially carry out an analysis of the applicability to the Tevatron and concept for implementation. Then decide whether to proceed to an R&D phase and again decide on proceeding to production.

Description of Change:
Based on the review committee recommendations, this task has been dropped from the project plan. Further conceptual work will however continue. The issue will be re-visited in April 2004, if further studies seem to demonstrate the need, efficacy of the scheme and readiness of the project to proceed to an engineering prototype design. The work carried out to date has been of an exploratory nature in a scenario of single wires placed at technically feasible machine positions. A detailed project with a clear strategy for the correction scheme, its robustness, its operation and performance evaluation needs to be worked out before it is reconsidered.

WBS 26.4.4. INCREASED HELIX SEPARATION
(Scope reduction)

WBS Description of affected tasks:
The orbits and helix separation will be improved in a series of steps, including optimization of the present system, the installation of polarity switches to allow more flexibility and upgrades to the separator system. Two upgrades are under consideration - upgrade to the existing separators to allow operation at higher voltages and adding new separators, including longer separators at the interaction regions.

Description of Change:
The revised scope of this project is as follows:

- build polarity switches for all separators
- install six additional separators, that are presently being fabricated, in the arcs
- explore helix schemes to optimize separation
- make serious efforts to improve present separator performance (operating at higher voltages, improving surface properties)

- explore the use of additional shorter separators in the IR instead of the proposed longer separators

It was decided not to build longer separators for the interaction regions, but to include an option in the project plan to build four shorter separators which would provide ~14-17% increase in separation. This option will be exercised depending on the outcome of the voltage studies for the existing separators. Two spares will be built if this option is invoked.

The project has been considerably simplified because only 6 new separators will be built instead of 14 separators proposed earlier. This also results in considerable reduction in cost and time.

WBS 26.4.6.4 TEVATRON BPM SYSTEM UPGRADE

(Cost increase)

WBS Description of affected tasks:
Upgrade the Tevatron BPM system. The v1.0 estimates were based on the recent Recycler BPM upgrade - which was the same scale of project and probably a similar implementation. Tevatron is more complex due to the need to measure both proton and pbar beams.

Description of Change:
The number of channels to be instrumented has doubled since the previous estimate. This change in the scope was motivated by the desire to measure both proton and antiproton beams when they are both present in the Tevatron, which requires two sets of pickups to be instrumented. The complexity involved in the technology may result in some delay in the schedule for completion. After a review in December 2003, decision has been made to proceed with a technical design based on modified EchoTek digital down-converter board (commercial board, used to upgrade the Recycler BPMs last year).

WBS 27.1 BEAM LOSS MONITOR/ ABORT LOGIC UPGRADE

(Scope change and Cost increase)

WBS Description of affected tasks:
Upgrade the Tevatron beam loss monitor and beam abort logic.

Description of Change:
Following the 16-house quench caused by the CDF "Tokyo Pot" incident (see section 1.5), a task force has been set up to review and upgrade the current beam loss monitor and abort system logic. Specifications for the upgrade are expected to be developed by March 2004. Preliminary cost estimates are $250 K and 60% contingency.

3.2 The Recycler Commissioning Plan

(Scope update and cost increase)

A plan to commission the Recycler and to fully integrate it into operations has been completed and included in v2.0. A detailed work plan along with performance criteria and milestones has been developed and included in the resource-loaded schedule. Here, we briefly outline the plan.

The Recycler plays a key role in the upgraded Run II, as a repository for large stacks of antiprotons. In order to maximize the stacking efficiency of the antiproton accumulator, small stacks of antiprotons are expected to be transferred to the Recycler, frequently. When electron cooling is operational and the accumulator has been upgraded to produce antiprotons at a rate of about 45×10^{10} per hour, the plan is to transfer a stack of 22×10^{10} antiprotons every 30 minutes. Each newly transferred stack will be cooled by a gated stochastic cooling system before getting merged into the main stack in the Recycler. With about 90% transfer efficiency, this would allow a stack of 600×10^{10} antiprotons to be collected in the Recycler, in about 15 hours. This stack of antiprotons will be used for collider operation in the Tevatron. The stack while it stays in the Recycler is to be cooled continuously by the electron cooling system.

The Recycler and electron cooling will be integrated into operations in two major steps. First, by summer of 2004, the Recycler itself will be commissioned, ready for the introduction of electron cooling. Second, electron cooling will be commissioned and used to cool antiprotons in the Recycler. The Recycler with electron cooling will then be integrated into collider operations. If operating scenarios where the Recycler can be used to improve integrated luminosity are identified, it will be used in that fashion, before electron cooling is commissioned.

To successfully commission and integrate the Recycler into operations, the following tasks need to be completed – (a) efficient transfer of antiprotons from the Accumulator to the Recycler via the Main Injector (requiring RF manipulations in the MI), with minimal beam loss and emittance dilution, (b) stacking and cooling in the Recycler (c) efficient and optimal extraction from the Recycler to create 36 equally populated, equal emittance bunches for injection into the Main Injector for Tevatron shot set-up. To this end, sets of specific performance criteria for different stages of operation (injection, stacking and equilibrium storing) to be met during the FY2004 efforts and for the final Run II luminosity goals have been developed, reviewed and approved. These criteria are shown in Table 3.1 and 3.2 and include specifications of beam lifetime, transfer efficiencies, stacking capacity and constraints on emittance growth for specific stack sizes. Since the chain of operations involve three different machines – the Accumulator, the Recycler and the Main Injector, the specification of performance criteria were also accompanied by operational responsibilities and parameter measurement techniques to be used. To help achieve these goals and ascertain them, a detailed commissioning plan has been developed. The detailed commissioning plan and the performance criteria document will be made available as a technical note.

Recycler FY2004 Performance Criteria (for antiprotons)

	Lifetime	**Longitudinal properties**	$\varepsilon_\perp \{\Delta \varepsilon_\perp\}$	**Comments**
MACHINE READINESS	≥ 150 hr	$\Delta p_{rms} < 2$ MeV/c	{≤6π mm-mrad/hr} growth rate	Zero-current, pencil beam
PERFORMANCE @ ≥ 100×10^{10}	≥ 100 hr	$\varepsilon_L \leq 100$ eV-s	≤ 10 π mm-mrad {≤ 3 π mm-mrad /transfer from MI}	Injection efficiency from MI ≥ 85%
GATED TRANSVERSE STOCHASTIC COOLING @ 20×10^{10} IN INJECTION BUCKET		Initial injected $\varepsilon_L \leq 15$ eV-s De-bunched < 50 eV-s	From 15 π mm-mrad to ≤ 10 π mm-mrad in 25 minutes	Injection efficiency from MI ≥ 85% for a 20×10^{10} batch
EXTRACTION PERFORMANCE		36 bunches @ 1.5 eV-s in 30 min.	≤ 10 π mm-mrad {≤ 3 π mm-mrad /transfer}	Extraction efficiency to MI ≥ 90%

Table 3.1. Recycler performance parameters to be achieved in FY2004. ε_L and $\varepsilon_\perp$ are the longitudinal and transverse 95%, normalized beam emittances, respectively.

Recycler Final Run II Goals (with electron cooling)

	Lifetime	$\varepsilon_L \{\Delta \varepsilon_L\}$	$\varepsilon_\perp \{\Delta \varepsilon_\perp\}$	**Efficiency/Stacking Performance**
EQUILIBRIUM PROPERTIES @ 600×10^{10}	≥ 150 hr	≤ 50 eV-s	≤ 10π mm-mrad {≤6π mm-mrad/hr}	Rapid transfers scenario

Table 3.2. Recycler performance goals for Run II after implementing the electron cooling.

The commissioning of the Recycler is well underway. Some of the performance criteria have already been met. The zero-beam current, pencil beam emittance growth have been measured to be < 6 π-mm-mrad and the beam lifetime to be >150 hours. The required performance with 100 x10^{10} antiprotons has been achieved. A new operational milestone of using the antiprotons from the Recycler in a collider store for high energy physics was reached on January 23, 2004.

4. Resource-Loaded Schedule

Version 2.0 of the resource-loaded schedule includes the project scope changes described in the previous Section. In particular, it includes a detailed plan for commissioning the Recycler, ready for the installation and commissioning of electron cooling. It also includes more detail in the planning for the other subprojects and a complete review and update of the cost and resource estimates. Following technical reviews over the last few months, the plans for several of the subprojects have been firmed-up and improved, and there are now only a few specific decision points remaining. The scope changes associated with v2.0 compared to v1.0 have been documented and approved via the change control process described in the appendix.

The resource-loaded schedule is maintained in Microsoft Project. Version 1.0 constituted 725 lines in the project data file (the work plan tasks and WBS roll-up tasks). Version 2.0 has 1360 lines. This doubling of the amount of data is due to both new material, with detailed plans included for the Recycler and the Tevatron BPM upgrade and with major revisions to sections such as the Tevatron helix separation plan, and to added detail in existing sections.

All the numbers and dates quoted in this Section for v1.0 refer to the resource-loaded schedule presented at the DOE review in July 2003. There are minor differences with the document sent to DOE on June 15, 2003 [Ref. 5].

4.1 Methodology

The same bottom-up method is used in building this revision of the plan as for v1.0. The leader of each subproject defines the Work Breakdown Structure for the subproject to an appropriate level for managing the work, along with the schedule logic, costs, durations and labor resources. Labor resources are entered as named individuals wherever possible, or as a generic labor category to be provided by a specified department.

Access to the accelerator tunnels is required for some specific tasks. It is assumed that access periods of one day can be scheduled into normal operations, along with maintenance work. Any tasks needing more than one day of access are scheduled during the shutdowns defined in the Fermilab Long Range Schedule.

A quality of estimate flag is assigned to each task indicating the confidence in the estimation (for both labor and M&S cost). These flags are interpreted in the following way:

- A = based on vendor information or engineered design – 20 percent contingency
- B = engineering concept, or experience with similar projects – 40 percent contingency
- C = conceptual design – 60 percent contingency

- D = scope not yet fully defined, use an estimate of the cost scale – 100 percent contingency

Labor is calculated in work-days, with a full-time equivalent (FTE) defined as 221 work-days per year, allowing for 15 percent vacation, holidays, and sick time. Labor costs are calculated using the current average SWF costs for each labor category.

4.2 Notation Changes

In order to conform to the Fermilab Project Accounting Work Package system, the Run II Upgrade Plan has been renumbered. WBS 20.26 refers to the Run II Luminosity Upgrades (WBS 1.3 in v1.0), and WBS 20.27 refers to the Maintenance and Reliability Upgrades (WBS 1.2 in v1.0). Run II Operations (designated WBS 1.1 in v1.0) is represented by the operating support for each of the machine and support departments. The number 20 in the new WBS scheme refers to the Accelerator Division and is dropped when referencing the task elements within the plan.

Since the major scope reviews are now completed, we have redefined one of the milestone classes to provide a more complete hierarchy. The milestones classes for v2.0 are:

A = top level that drive the luminosity projection – typically the completion of a major subproject
B = completion of a major subproject that does not drive the luminosity projection (in v1.0 the B classification was used for major scope decisions)
C = milestones internal to the project for tracking progress

4.3 Shutdown Schedule

The shutdown schedule used in v2.0 is consistent with the current Fermilab Long Range Schedule, with annual shutdowns as indicated below.

2004	13 weeks	8/23/04– 11/22/04
2005	8 weeks	8/8/05 – 10/3/05
2006	8 weeks	8/7/06 – 10/2/06
2007-9	8 weeks	last 8 weeks of fiscal year

4.4 Change Control for v2.0

The following change requests (discussed in Section 3) have been approved by the Associate Director for Accelerators:

- Addition of the Recycler plan – cost increase
- Update and re-scope of the Tevatron helix/separator plan – scope (and cost) reduction

- De-scope of the wire beam-beam compensation – scope (and cost) reduction
- De-scope of the Stacktail Betatron Cooling upgrade – scope (and cost) reduction
- Re-schedule of the Beam-sweeping subproject – milestone change
- Update of the electron-cooling cost and schedule – cost increase and milestone slip
- Update of the Tevatron BPM project – cost increase
- Upgrade of the Tevatron Beam Loss Monitor and Abort Logic – New project, cost increase

4.5 Run II Operational Support

The ongoing support for Run II Operations is not captured in the WBS of the resource-loaded schedule. This support includes accelerator operations itself, operational improvements including short-term (but continuous) improvements to operational equipment and software, and short-term maintenance and repair.

Based on accelerator operating experience, this ongoing work is estimated to require approximately $ 48 M per year for materials and services and labor over the FY04-06 time period (as detailed in the Fermilab Lab-Wide-WBS Element 1.1.1 Accelerator Maintenance and Operations).

The summary which follows in this section refers to the Luminosity Upgrades and long - term Maintenance and Reliability plan, and does not include the base operations support.

4.6 Cost Summary

Table 4.1 itemizes the Materials and Services (M&S) costs and the Labor costs at WBS Level 3 in v2.0, summed over the duration of the program. The contingency applied at the task level rolls up to a total contingency of 45 percent for M&S and 51 percent for Labor.

WBS	Name	M&S	SWF	Total
	Run II Upgrade Total (Base)	**$17,092,120**	**$18,844,746**	**$35,936,866**
	Run II Upgrade Total (Base+Contingency)	**$24,715,205**	**$28,455,567**	**$53,170,772**
26	**Luminosity Upgrades**	**$13,629,260**	**$17,769,956**	**$31,399,216**
26.1	**Protons on Pbar Target**	**$1,989,538**	**$1,253,954**	**$3,243,492**
26.1.1	Slip Stacking	$920,060	$447,889	$1,367,949
26.1.2	Pbar Target and Sweeping	$92,550	$104,955	$197,505
26.1.3	MI Upgrades	$976,928	$643,512	$1,620,441
26.1.4	Booster-MI Cogging	$0	$57,597	$57,597
26.2	**Pbar Acceptance**	**$1,879,365**	**$2,589,496**	**$4,468,861**
26.2.1	Lithium Lens Upgrades	$491,592	$627,262	$1,118,854
26.2.2	AP2 and Debuncher Acceptance	$1,387,773	$1,962,234	$3,350,007
26.3	**Pbar Stacking and Cooling**	**$3,983,649**	**$3,951,045**	**$7,934,693**
26.3.1	Stacking and Cooling Integration	$0	$464,404	$464,404
26.3.2	Debuncher Cooling	$0	$21,837	$21,837
26.3.3	Stacktail Cooling	$1,039,435	$392,876	$1,432,311
26.3.4	Recycler Stacking and Cooling	$796,698	$1,175,948	$1,972,646
26.3.5	Electron Cooling	$1,595,480	$1,109,650	$2,705,130
26.3.6	Rapid Transfers	$552,036	$786,329	$1,338,365
26.4	**Tevatron High Luminosity**	**$5,776,708**	**$8,436,155**	**$14,212,862**
26.4.1	Tevatron Task Force	$0	$1,883,260	$1,883,260
26.4.2	Beam-beam Limitations	$5,000	$487,097	$492,097
26.4.3	Active Beam-Beam Compensation	$1,296,660	$1,271,188	$2,567,848
26.4.4	Increased Helix Separation	$1,564,828	$1,132,258	$2,697,086
26.4.5	Luminosity Leveling	$0	$10,184	$10,184
26.4.6	Improved Control and Diagnostics	$2,530,512	$2,701,794	$5,232,306
26.4.7	Tevatron Vacuum Improvements	$93,780	$13,029	$106,809
26.4.8	Tevatron Alignment	$285,928	$937,345	$1,223,273
26.6	**Project Management**	**$0**	**$1,539,308**	**$1,539,308**
26.6.1	Management Oversight	$0	$1,539,308	$1,539,308
27	**Maintenance and Reliability**	**$3,462,860**	**$1,074,790**	**$4,537,650**

Table 4.1: Base costs in Actual Year $ for the Run II, with the Luminosity Upgrades, broken out at Level 3.

COST COMPARISON TO V1.0

Table 4.2 compares the total cost in $FY03 between v2.0 and v1.0. The base M&S for the Maintenance and Reliability Upgrades, WBS 20.27, are reduced by $100K compared to v1.0 due to a reduction in the cost estimated for two of the task elements. For the Luminosity Upgrades, WBS 20.26, the M&S costs are listed at Level 3 in Table 4.3 to allow a more detailed comparison.

$K (in $FY03)	**v2.0**	**v1.0**
M&S Base estimate	16,461	14,965
M&S Contingency estimate	7,356	7,462
M&S Total	**23,817**	**22,427**
Labor Base estimate	17,911	18,194
Labor Contingency estimate	9,181	9,706
Labor Total	**27,092**	**27,900**
M&S+Labor Total	**50,909**	**50,327**

Table 4.2 M&S and labor costs for the 20.26 and 20.27 total in $FY03, v2.0 compared to v1.0.

The contingency rollup in v2.0 [v1.0] is 45% [50%] for M&S and 51% [53%] for labor.

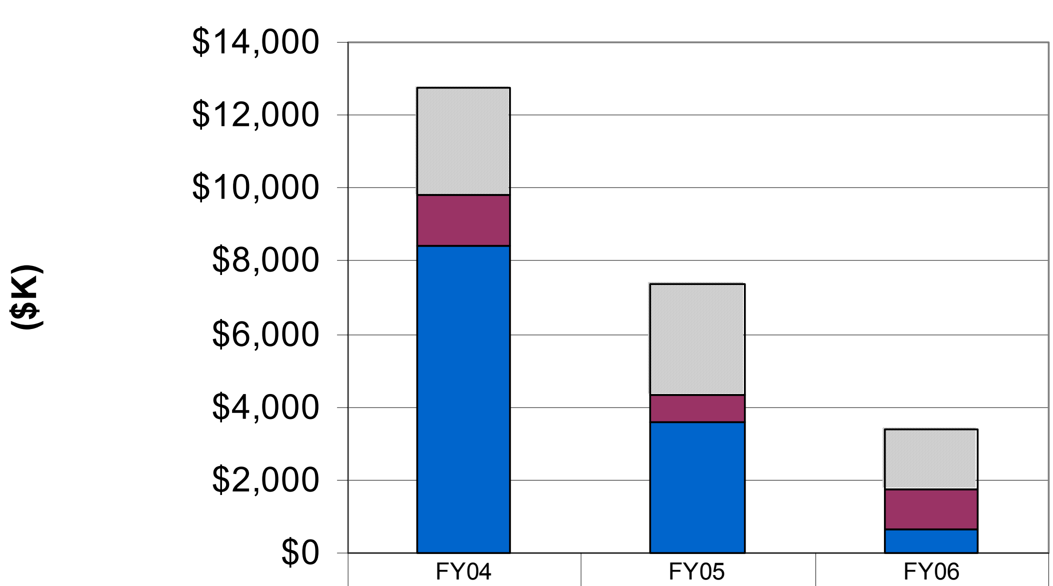
M&S AND LABOR PROFILES

The M&S obligations profile is shown in Fig 4.1. The contingency estimate of 45 percent is determined by the bottom-up estimation process described above, and allocated to the three years FY04-06 with a higher proportion to later years. The *base* projection is consistent with the budget allocated for these upgrades in Fermilab budget planning, with an available contingency of 38%, which is adequate at this stage in the projects.

The labor resource profile is shown in Fig. 4.2. This profile includes the estimated need for all labor on the projects. While the majority of this labor is provided by the Accelerator Division, significant resources are provided from other divisions at Fermilab and from other institutions.

WBS	NAME	v2.0 Base M&S	v1.0 Base M&S	Difference
26	**Luminosity Upgrades**	**$13,158,426**	**$11,561,460**	**$1,596,966**
26.1	**Protons on Pbar Target**	**$1,911,500**	**$2,331,500**	**-$420,000**
26.1.1	Slip Stacking	$895,000	$1,310,000	-$415,000
26.1.2	Pbar Target and Sweeping	$91,500	$96,500	-$5,000
26.1.3	MI Upgrades	$925,000	$925,000	$0
26.1.4	Booster-MI Cogging	$0	$0	$0
26.2	**Pbar Acceptance**	**$1,796,960**	**$1,870,960**	**-$74,000**
26.2.1	Lithium Lens Upgrades	$471,000	$463,000	$8,000
26.2.2	AP2 and Debuncher Acceptance	$1,325,960	$1,407,960	-$82,000
26.3	**Pbar Stacking and Cooling**	**$3,871,998**	**$2,256,000**	**$1,615,998**
26.3.1	Stacking and Cooling Integration	$0	$0	$0
26.3.2	Debuncher Cooling	$0	$0	$0
26.3.3	Stacktail Cooling	$1,004,000	$1,171,000	-$167,000
26.3.4	Recycler Stacking and Cooling	$774,998	$0	$774,998
26.3.5	Electron Cooling	$1,556,000	$568,000	$988,000
26.3.6	Rapid Transfers	$537,000	$517,000	$20,000
26.4	**Tevatron High Luminosity**	**$5,577,968**	**$5,103,000**	**$474,968**
26.4.1	Tevatron Task Force	$0	$0	$0
26.4.2	Beam-beam Limitations	$5,000	$5,000	$0
26.4.3	Active Beam-Beam Compensation	$1,250,000	$1,380,000	-$130,000
26.4.4	Increased Helix Separation	$1,488,500	$1,847,000	-$358,500
26.4.5	Luminosity Leveling	$0	$0	$0
26.4.6	Improved Control and Diagnostics	$2,463,468	$1,500,000	$963,468
26.4.7	Tevatron Vacuum Improvements	$90,000	$90,000	$0
26.4.8	Tevatron Alignment	$281,000	$281,000	$0

Table 4.3: Comparison of Base M&S costs for Luminosity Upgrades at WBS Level 3 in $FY03.



	FY04	FY05	FY06
Contingency	$2,946	$3,041	$1,647
27: Maint & Rel. Base	$1,383	$739	$1,083
26: Lum Upgrades Base	$8,437	$3,605	$651

Fig. 4.1: M&S Cost profile for FY04 - FY06 in Actual Year $. M&S Costs are fully obligated by the end of FY06.

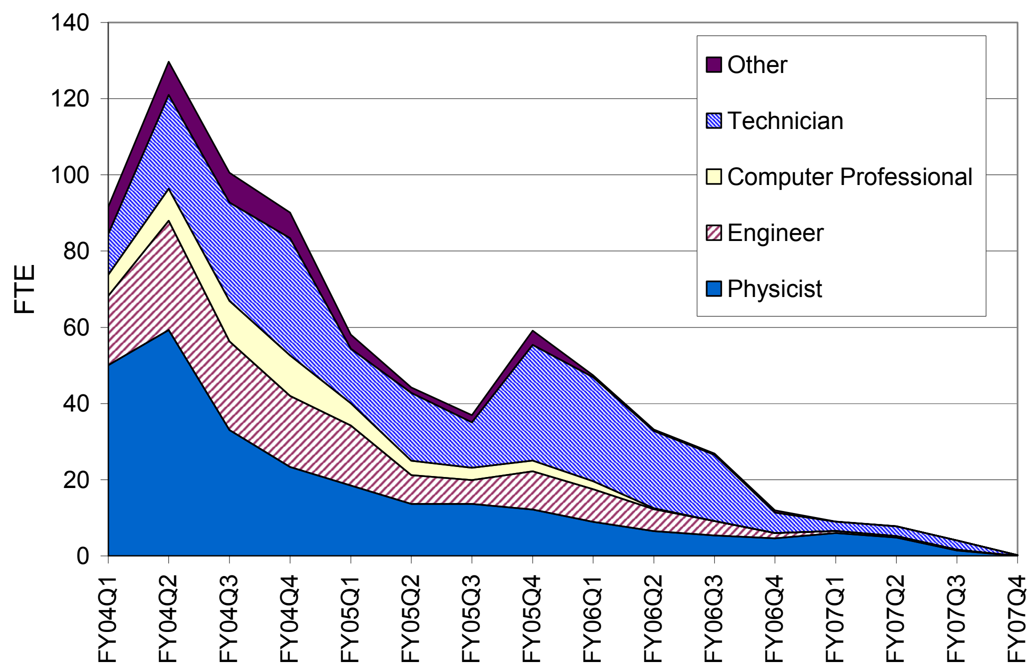


Fig. 4.2: Labor profile, shown quarterly for FY04 through FY07 in FTE.

4.7 Schedule Summary

The top level milestones are a set of start dates for operating phases. Each phase represents the introduction of a new way of operating the accelerator complex for Run II. These “start of phase” dates, along with the completion dates for the projects which directly feed into them, constitute the class A milestones.

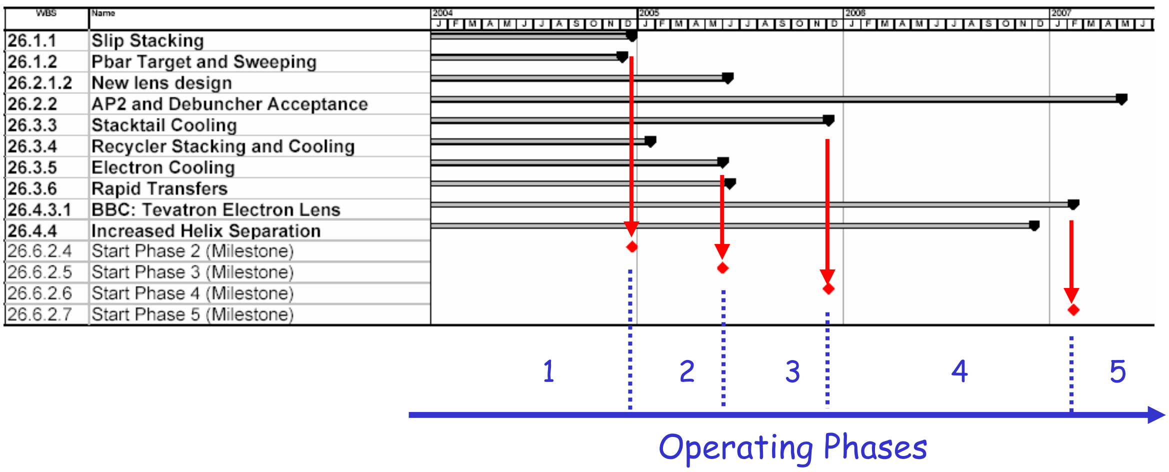


Fig 4.3: Project Completion and Operating Phases. Phase 1 is the current phase. Slip stacking and the target upgrades are required for Phase 2, electron cooling for Phase 3, the Stacktail upgrade for Phase 4, and completion of the Tevatron upgrades for Phase 5.

These phase milestones serve as the start of a learning curve for the operation of this new phase in the luminosity *design* projection described in the next Section. A second set of phase milestones, with fixed delay from the primary set, is used for the *base* luminosity projection.

The complete set of class A milestones is included in Table 4.3, where the dates are compared to those in v1.0. The most significant change for the luminosity projection is a delay by three months in the start of phase 3. This is a result of a significant update to the installation and commissioning plans for the Recycler and electron cooling.

WBS	Milestone	v2.0	v1.0	Diff in Days	Note
26.1.2.1.4.3	New Target in Operation (Milestone)	02/02/04	12/30/03	34	
26.6.2.2	Review Recycler Commissioning Plan	02/09/04	12/16/03	55	
26.3.4.9.16	Recycler commissioned for Electron cooling	06/01/04	7/2/04	-31	
26.1.2.2.4.2	Beam Sweeping Operational (Milestone)	08/25/04	1/21/04	217	[1]
26.4.4.3.1.5	New standard separators operational	10/25/04			
26.2.2.10	Initial AP2&DB Improvements Complete (Milestone)	11/22/04			
26.1.1.10	Slip Stacking Operational	12/23/04	12/14/04	9	
26.6.2.4	Start Phase 2 (Milestone)	12/23/04	12/14/04	9	[2]
26.3.5.12	Electron Cooling Operational (Milestone)	06/01/05	1/25/05	127	
26.6.2.5	Start Phase 3 (Milestone)	06/01/05	2/22/05	99	[2]
26.2.1.4	New Lens Operational (Milestone)	06/10/05	4/11/05	60	
26.3.6.7	Rapid Transfers Operational (Milestone)	06/14/05	5/5/05	40	
26.2.2.11	Intermediate AP2&DB Improvements Complete (Milesto	10/03/05			
26.3.3.1.9	Stacktail Momentum Operational (Milestone)	12/06/05	11/17/05	19	
26.6.2.6	Start Phase 4 (Milestone)	12/06/05	11/17/05	19	[2]
26.2.2.12	Final AP2&DB Improvements Complete (Milestone)	10/02/06	12/4/06	-63	
26.4.4.4.14	New helix operational	12/05/06	3/22/07	-107	
26.4.3.1.11	TEL System Operational	02/12/07	5/23/07	-100	
26.6.2.7	Start Phase 5 (Milestone)	02/12/07	5/23/07	-100	[2], [3]

Table 4.3: Class A milestones in v2.0 and v1.0. Where dates are missing in v1.0, the plan has been updated in v2.0 and there are no equivalent milestones.

[1] The Beam-sweeping subproject was rescheduled to better match the priority of the work, as described earlier in this document
[2] The largest change in the phase milestones is a 3 month slip for the start of phase 3. This results from the update to the Recycler and Electron Cooling commissioning plans.
[3] The start of phase 5 is significantly earlier in v2.0 due to the updated shutdown schedule. v1.0 included a long shutdown starting in 2006 to allow major upgrades to the detectors. The present scope of upgrades for the experiments can be accomplished with the shutdown schedule in v2.0.

4.8 Cost and Schedule Tracking

As described in the appendix, the status of progress in terms of cost and schedule is presented each month to the Accelerator Program Management Group. This monthly tracking consists of information from the Level 2 and 3 managers and from the cost accounting system. At this time accounting of actual costs is under development.

Each month the Level 2 and 3 managers complete an evaluation of status against the resource-loaded schedule, indicating the % completion for each task, and monitoring progress towards each milestone. Any foreseen cost changes are reported. The results are presented at the monthly PMG meeting. If an update to the plan is required which exceeds the thresholds described in the appendix to this document, a change request document is submitted to the Associate Director for Accelerators.

5. Luminosity Projection

The modeling used to estimate the luminosity projection was described in Ref [5] and the references therein.

There are three classes of parameters in the estimation of the luminosity.

1. Performance parameters determine the luminosity performance in a single store. These include antiproton stacking rate, transfer efficiencies, and bunch intensities.
2. Operating scenario parameters define operating efficiency and include the amount of time scheduled for HEP rather than studies and maintenance, down time due to Tevatron quenches, and equipment failure.
3. Learning rates when new upgrades are introduced, and recovery rates after each scheduled shutdown.

In all cases the parameters used are long-term averages, based on operating experience, rather than best achievable.

The current projection includes the following improvements over v1.0.

- Parameters are updated from operating experience. Current typical values are included in the table below.
- Dates for the shutdowns and operating phases are taken from v2.0 of the resource-loaded schedule. An additional week is added to each shutdown corresponding to turn on of the complex. No luminosity is delivered to the experiments during this week.
- The use of antiprotons in commissioning the Recycler and Electron Cooling is included explicitly as an up-time parameter in the antiproton stacking for HEP. Additional commissioning associated with the introduction of each operating phase is included as a learning curve in the luminosity projection. Operational maintenance studies, and studies associated with the development of the upgrade projects themselves are taken into account in the number of HEP hours per week.

As for v1.0, two luminosity projections are presented. The *design projection* represents the expected average performance of the complex with the successful completion of the upgrades as planned. The *base projection* includes both reduced performance from the upgrades and schedule slip. The projections, which are illustrated in Fig. 5.1, are discussed further below.

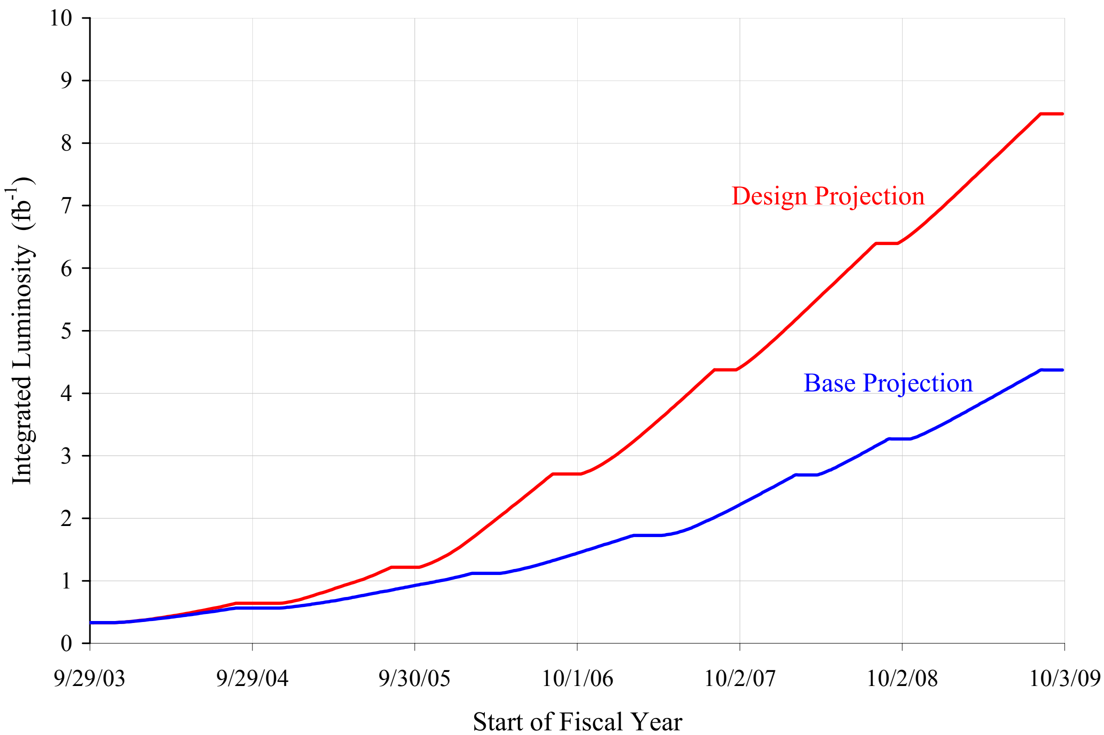


Fig 5.1: *Design* and *Base* luminosity projections.

5.1 Design and Base Projections

The performance parameters used in the *design projection* are not the goals or specifications set for each of the projects; engineering design margin is maintained. Rather, they represent an operational level for the complex with the successful completion of each project.

The parameters achieved at the end of each operating phase are listed in Table 5.1 for the *design projection*.

In the luminosity projection a final phase 6 is added. In this phase the upgrade program is complete and there are no associated study shifts. Studies associated with maintaining operational performance continue.

An equivalent set of parameters is used for the *base projection*. The parameters are compared for the two projections at the completion of phase 6, at the end of the upgrade program, in Table 5.1.

	12/31/03 to 1/15/04	**Design Projection**						**Base Proj**	**units**
Performance parameters at end of Operating Phase		1	2	3	4	5	6	6	
Initial Luminosity	38	62	85	125	224	275	275	157	$x10^{30}cm^{-2}sec^{-1}$
Integrated Lum per week	7.7	11.3	16.4	23.3	40.4	46.0	47.3	27.8	pb^{-1}
Average Store Hours per Week	111.9	85.5	88.8	91.4	94.0	96.7	99.3	92.3	
Average Lum Lifetime	15	13	13	11	10	9	9	10	Hours
Number of Protons per bunch	223	260	260	260	260	270	270	260	$x10^{9}$
Number of Pbars per bunch	23.6	31.1	40.9	59.8	104.3	126.5	126.5	74.9	$x10^{9}$
Proton Emittance	28.0	29.0	27.0	26.0	25.0	25.0	25.0	25.0	π-mm-mrad
Pbar Emittance	12	13	13	14	14	15	15	15	π-mm-mrad
Pbar Transfer Eff. To Low Beta	0.75	0.8	0.8	0.8	0.8	0.8	0.8	0.75	
Zero Stack Stacking Rate	11	18	26	26	40	46	46	31.5	$x10^{10}$/hour
Average Stacking Rate	4.7	9.3	12.7	18.6	32.4	39.3	39.3	24.8	$x10^{10}$/hour
Stack Size transferred	113	140	184	269	470	569	569	360	$x10^{10}$
Pbar Production	15	17	20	20	28	32	32	25	$x10^{-6}$
Protons on Target	4.8	5.0	8.0	8.0	8.0	8.0	8.0	7.0	$x10^{12}$
Pbar cycle time	2.4	1.7	2.2	2.2	2.0	2.0	2.0	2.0	Sec.
Pbar stacking fraction	0.60	0.75	0.75	1.00	1.00	1.00	1.00	1.00	

Table 5.1: Parameters in the Luminosity Projection. Column 2 illustrates typical operating performance in January 2004. Columns 3 through 8 indicate the parameters in the *design* projection on completion of each phase, and for comparison, column 9 indicates the parameters for the *base* projection at completion of phase 6.

The *base* projection also includes a delay in implementing the operating phases, with three months added for the start of phase 2 and six months for the start of all other phases. This is discussed further in the next Section. It is assumed that the scheduled shutdowns are delayed appropriately to match delays in the projects.

Fig. 5.2 illustrates the phases in a projection of the weekly integrated luminosity. Again, this is a long-term average performance, so individual weeks are expected to be above or below these curves.

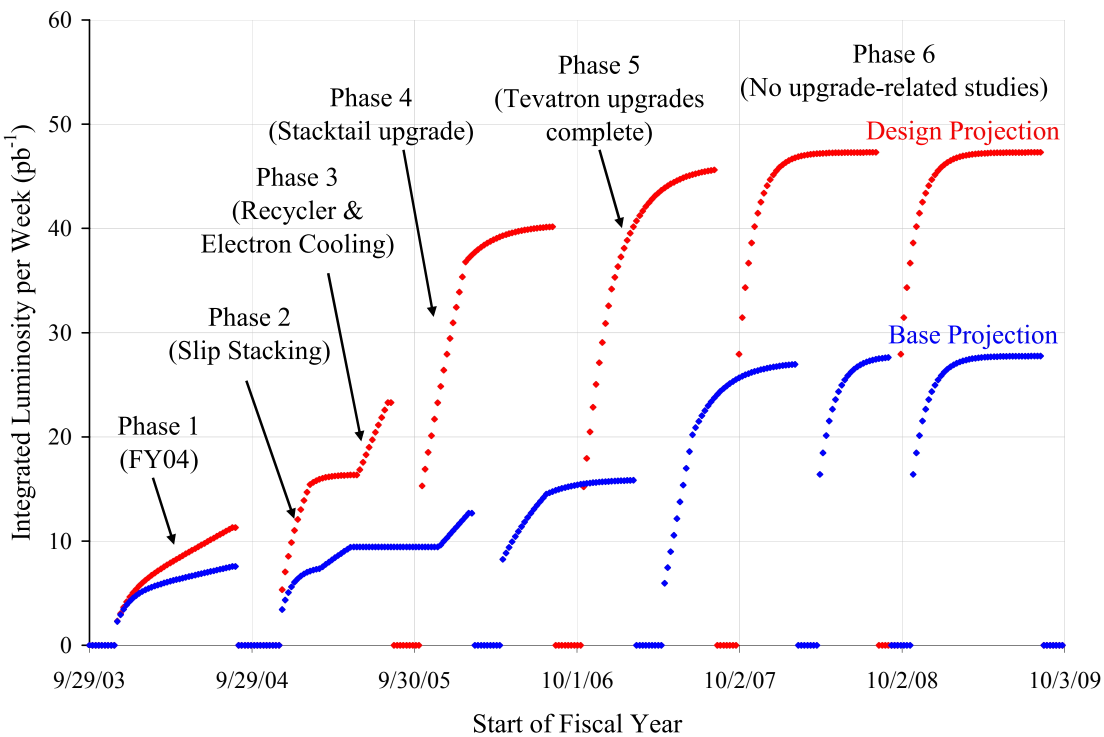


Fig. 5.2: Weekly integrated luminosity for the *Design* and *Base* projections.

Fiscal Year	Design (fb^{-1})	Base (fb^{-1})
FY03	0.33	0.33
FY04	0.64	0.56
FY05	1.2	0.93
FY06	2.7	1.4
FY07	4.4	2.2
FY08	6.4	3.3
FY09	8.5	4.4

Table 5.2: The integrated luminosity achieved at the end of each fiscal year.

5.2 Performance Risks and Mitigation

The *design* projection represents the expected performance on successful completion of the upgrade projects, with design margin maintained in the specifications for each project. There are three categories of risk associated with the plan.

1. SIGNIFICANT TECHNICAL RISK

While there has been excellent progress with both Recycler commissioning and Electron Cooling R&D over the last several months, these projects still present the highest technical risk. In particular, successful cooling of antiprotons in the real world environment of the Recycler is challenging and the R&D character of these projects will continue until this is demonstrated. A reduced performance level is included in the parameters used for the *base projection*, but nevertheless operation of electron cooling in the Recycler is assumed.

The upgrade plan is arranged such that successful commissioning of the Recycler and Electron Cooling are required (start of phase 3) before installation of the upgrade to the Accumulator stacktail cooling system (start of phase 4). In order to upgrade the stacktail system, the duty of maintaining and cooling large stacks of antiprotons must be offloaded from the Accumulator to the Recycler. If the Recycler is unable to fill this role, large stacks will continue to be supported in the Accumulator and the stacking rate will be limited by the present stacktail system. The other upgrades would proceed and contribute to increased performance (although the full increase in antiproton production and collection would not be required), but the stacking rate would limit the intensity of the antiproton bunches. This would result in a luminosity projection somewhat below that for the *base projection*.

2. PERFORMANCE RISK

In addition to the specific risks discussed above, several aspects of the upgrades are technically challenging. This is taken into account in the *base projection* with conservative values for the performance parameters. While the risk of underperformance is independent for each of the projects, *all* of them are assumed to under perform in this luminosity projection. The degree of degradation for each parameter reflects the level of technical risk associated with the corresponding project. For example we consider it more challenging to achieve the goals for antiproton acceptance and stacking rate, than to achieve the proton intensity per bunch in the *design* projection, so the parameters representing their performance are degraded further. A comparison of parameters in the two projections for phase 6 is shown in Table 5.1.

3. SCHEDULE RISK

The mitigation of schedule creep is accomplished by monitoring project status against the plan (see Section 4.8, Cost and Schedule Tracking) and determining where corrective action is needed. Significant schedule delay can result however from the technical risk described above, where more time might be needed to overcome technical problems.

Resource limitations can also delay project completion. The critical labor resources are largely independent for the subprojects. So the risk of delays for both technical and resource reasons are themselves largely independent for each phase milestone. That is, other than the requirement discussed above that phase 4 should start after a successful start of phase 3, the date for the start of each operating phase is independent and delay in any one does not delay the others.

The *base projection* includes a delay in the start of *each* phase, in addition to the performance reduction for every project. Three months are added to the start of phase 2 and six months to the start of phases three through five.

We therefore consider the *base* projection to represent a conservative estimate which represents both the performance and schedule risk associated with each project. Additional risk associated with the Recycler and electron cooling is not taken into account. This risk will be eliminated when successful cooling of antiprotons is achieved in early 2005.

6. Conclusion

Since the DOE review in July 2003, there has been excellent technical progress.

- A plan was developed to resolve vacuum problems in the Recycler and was successfully executed during the shutdown in fall 2003. Commissioning of the machine, following the plan included in v2.0, is proceeding extremely well.
- A major undertaking of magnet alignment and repair work in the Tevatron was also successfully completed during the fall 2003 shutdown. As a result, significant improvements have been seen in Tevatron operations.
- The progress on the other projects, summarized in this document, has been very good, and we are well on track for starting phase 2 as expected at the end of the calendar year 2004.

As summarized in this report, v2.0 of the Run II Luminosity Upgrade Plan represents a major update to the plan presented to DOE on June 15, 2003.

- A commissioning plan is included for the Recycler, with both a detailed work plan and a set of performance milestones.
- Following a series of technical reviews included in v1.0 of the Run II Luminosity Upgrade Plan, the scopes of sub-projects have been reviewed and defined.
- The cost and resource estimates for the Plan have been reviewed and updated.
- The parameters used in the luminosity projections have been updated to reflect ongoing operational experience and the scope revisions to the upgrade elements.

The result is a major update to the resource-loaded schedule, v2.0, which includes a more detailed work plan. The estimates for cost, schedule and luminosity performance have been updated.

The Run II Luminosity Upgrade
at the Fermilab Tevatron

APPENDIX

Management Procedures for the Run II Upgrades

January 30, 2004

A. Management Procedures

For many years, as part of its normal operations, the Fermilab Accelerator Division has been carrying out upgrades to increase the luminosity of the Tevatron Collider. This document, "The Run II Luminosity Upgrade at the Fermilab Tevatron – v2.0 Project Plan and Resource-Loaded Schedule (RLS)", provides a complete description of the elements of this activity beginning in FY 2003. This Plan is updated regularly to reflect progress, along with changes in scope and schedule. This Appendix describes the management procedures that the Fermilab Directorate expects the AD and Run II Upgrade Organization to use in defining the scope and goals, developing plans, monitoring, coordinating, and capturing these activities in a WBS structure and a long range plan.

Specifically, the Plan documents the objectives of the upgrades, performance criteria, WBS structure, funding and manpower requirements, management structure and philosophy. This Appendix will be limited to management systems and procedures, reporting and meetings, benchmarks, control levels, performance monitoring, and change control management.

"Run II is not a construction project. Run II is a complex campaign of operations, maintenance, upgrades, R&D, and studies" (D. Lehman, July 24, 2003). Since this is not a formal DOE Project, the elements of these management procedures have been simplified to provide flexibility to accomplish this complex campaign while providing adequate control to effectively attain the goals of the Plan.

A.1 WBS Structure and Funding

The Run II Luminosity Upgrade Work Breakdown Structure (WBS) is shown to Level 2 in Fig. A1. In order to provide strict consistency with the Fermilab Project Accounting system, the notation of the highest WBS elements have been changed from 1.2 and 1.3 to 20.27 and 20.26, respectively. The WBS and management structure reflects the budget structure.

The cost estimate described in the Plan includes the materials, services, and labor for the Run II Luminosity Upgrade which sum over upgrades, R&D, and accelerator studies, beginning in FY 2003 and extending until anticipated completion of the upgrades in 2007.

The Run II Luminosity Upgrade receives its funding through the normal Fermilab annual financial plan. The allocations and directions relevant to the Run II Luminosity Upgrade funds are forwarded by the Fermilab Director to the Fermilab Accelerator Division (AD) for use by the Run II Luminosity Upgrade Project Manager. Other Fermilab Divisions and Sections (CD, TD, PPD, BS, ES&H, FESS) provide labor in support of the Run II Luminosity Upgrade.

Any change to the Run II Luminosity Upgrade funding profile approved in the Run II Luminosity Upgrade Plan will be proposed to the Fermilab Director jointly by the Head of the Accelerator Division and the Run II Luminosity Upgrade Project Manager. A proposed change must consider a revised cost estimate, the revised funding profile, and a revised schedule for consideration and approval as a directed change.

Effective management of the Run II Luminosity Upgrade requires careful coordination of the activities of various departments and groups. The overall management structure is shown in Fig. A1, embedded in the Fermilab and AD organization structure as the WBS Level 2 elements, and continues to WBS Level 3 in Fig. A2. These figures identify the Level 1, Level 2, and Level 3 Managers.

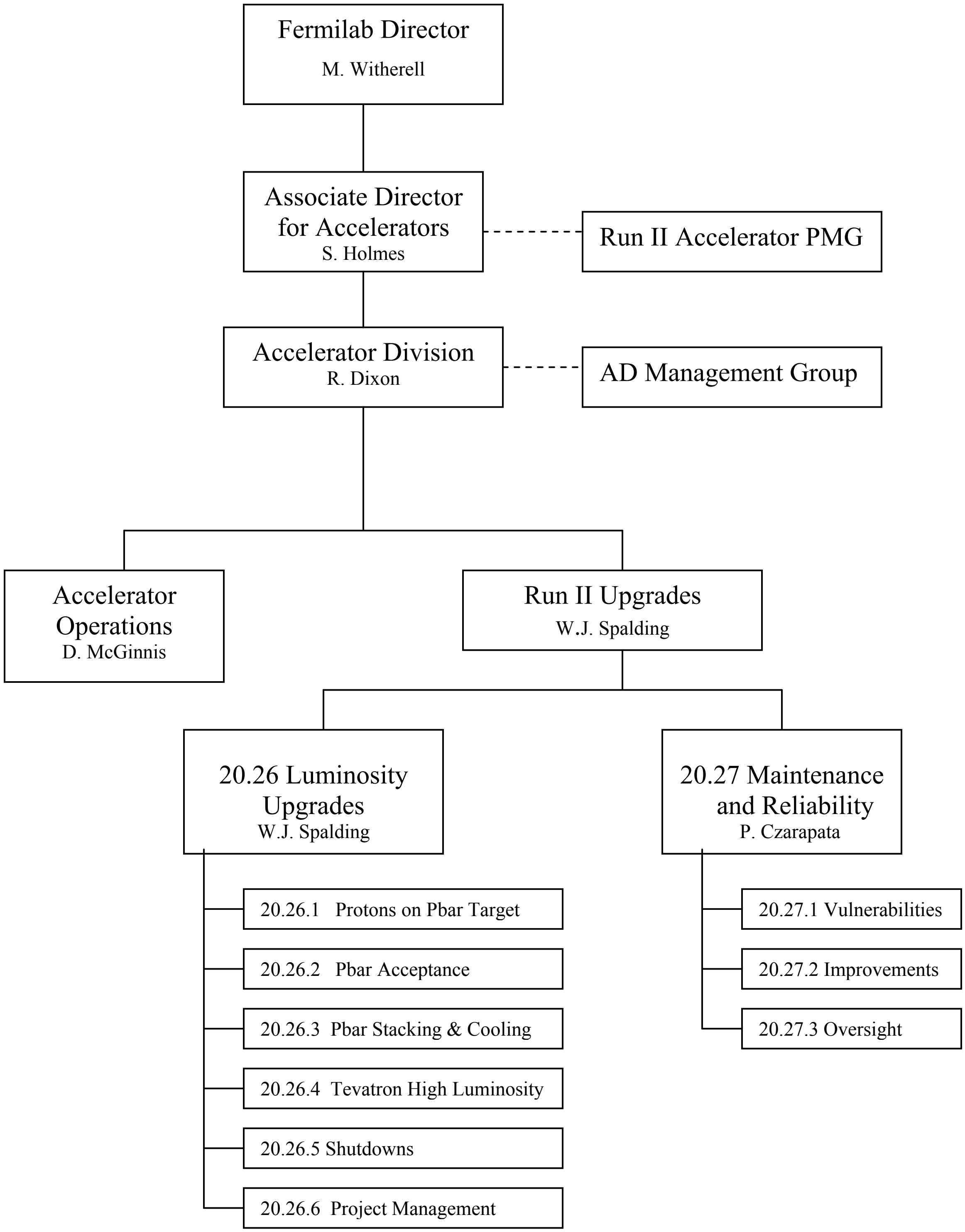


Fig. A1. Schematic of the Run II Luminosity Upgrade Organization to WBS Level 2 (20.26.X, 20.27.X), showing close relationship to Accelerator Operations. Dotted lines indicate advisory functions.

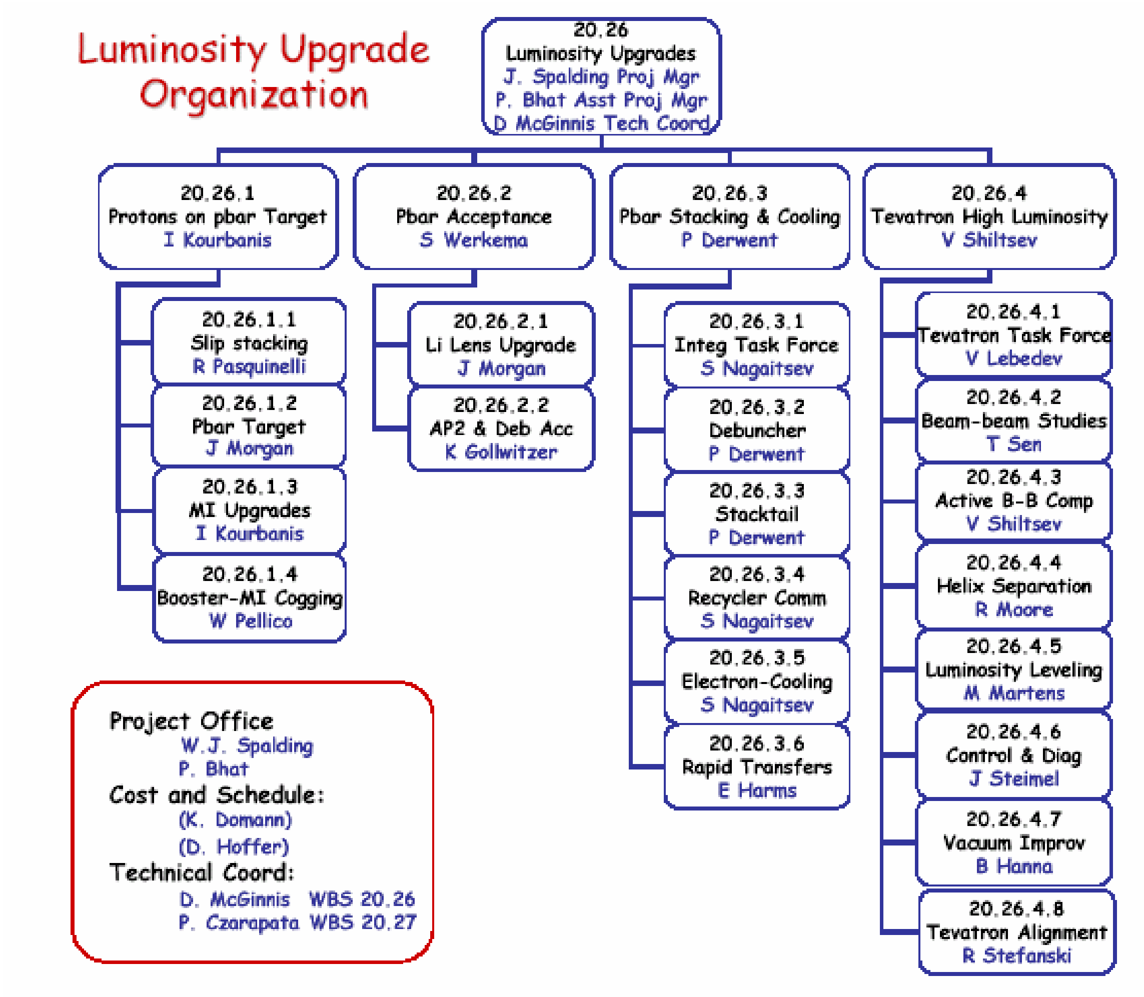


Fig. A2. Outline of WBS 20.26 Luminosity Upgrade to WBS Level 3 (20.26.X.X) including Level 3 Manager assignments.

A.2 Management Philosophy and Responsibilities

The multi-faceted nature of the Run II Luminosity Upgrades, which includes the construction, installation, and commissioning of many diverse, but inter-related accelerator systems, by teams from many Fermilab Divisions and Sections as well as from universities and other laboratories, dictates a management structure that is sufficiently flexible to meet the requirements of these different elements.

The following sections describe the line management responsibilities for the Run II Luminosity Upgrade.

FERMILAB DIRECTOR

The Fermilab Director is responsible to the Universities Research Association and the Department of Energy for the successful operation of the Fermilab Accelerator complex, of which the Run II Luminosity Upgrade is a major component. The Director approves the scope of the upgrades and authorizes funding**.**

FERMILAB ASSOCIATE DIRECTOR FOR ACCELERATORS

The Associate Director for Accelerators is responsible for the administration of the Fermilab Accelerator Division and the Technical Division. In this position, the Associate Director for Accelerators meets as necessary with the Run II Luminosity Upgrade management to help allocate resources from the organizations, the Accelerator Division and the Technical Division, reporting to that office. The Associate Director for Accelerators serves as Chairperson of the Run II Accelerator PMG.

RUN II ACCELERATOR PROJECT MANAGEMENT GROUP

The Run II Accelerator Project Management Group (PMG) will provide continuing oversight of the entire Run II Luminosity Upgrade. The PMG also functions as the Laboratory's Change Control Board. The PMG is responsible for considering Change Requests that meet the criteria detailed in Section 4.7 and advising the Director in that regard. The PMG is also a forum for the discussion and assignment of Fermilab resources in support of the Run II Luminosity Upgrade. The PMG consists of the following members:

- Fermilab Director (or designee)
- Fermilab Associate Director for Accelerators
- Run II Luminosity Upgrade Project Manager
- Accelerator Division Head or designee
- Particle Physics Division Head or designee
- Technical Division Head or designee
- Computing Division Head or designee
- Manager of the DOE Fermi Area Office or designee (Observer)
- Spokespersons of the CDF and D0 Experiments or designees

The Fermilab Associate Director for Accelerators serves as Chairman of the PMG.

FERMILAB ACCELERATOR DIVISION

The Head of the Fermilab Accelerator Division (AD) is responsible for accelerator systems including those provided by the Run II Luminosity Upgrade. The Accelerator Division Head appoints the Run II Luminosity Upgrade Project Manager. The Level 1, 2, and 3 managers are all members of the Accelerator Division. Although there are substantial contributions from the other Fermilab Divisions and Sections, universities, and other laboratories, the AD is the primary source of leadership and manpower for this upgrade. The Run II Luminosity Upgrade Project Manager is an Assistant Head of the Accelerator Division. The AD has created the Run II Luminosity Upgrade Project Office for line management of the personnel directly assigned to the Run II Luminosity Upgrade. The AD Head reports to the Fermilab Director through the Associate Director for Accelerators. The AD Head is a member of the Run II Accelerator Project Management Group. The AD Head has line responsibility for the ES&H related to the Run II Luminosity Upgrade.

ACCELERATOR DIVISION MANAGEMENT TEAM

The AD Management Team, consisting of the Division Head, Deputy Division Head, Associate Division Head for Accelerators, Associate Division Head for Engineering, Associate Division Head for NuMI, Assistant Division Head for Run II Upgrade (Project Manager), Assistant Head for Controls and Instrumentation, and Advisor to the Accelerator Division Head, regularly meets and works with the AD Head to determine and implement both the short- and long-term strategies and plans for managing the AD activities, of which the Run II Luminosity Upgrades is just one component.

RUN II LUMINOSITY UPGRADE PROJECT MANAGER

The Run II Luminosity Upgrade Project Manager is a Fermilab employee who is appointed by the Head of the Fermilab Accelerator Division and is responsible for all aspects of the Run II Luminosity Upgrade. The Project Manager reports to Head of the Accelerator Division.

The Head of the Accelerator Division has delegated the following responsibilities to the Run II Luminosity Upgrade Project Manager:

- Administering, planning, organizing, and controlling the Run II Luminosity Upgrade to meet the technical, cost, schedule and ES&H objectives;
- Fiscal authority over Fermilab funds allocated to the upgrades;
- Monitoring expenditures included in the Resource-Loaded Schedule Plan;
- Tracking and reporting of deviations from benchmark scope, schedules and costs;

- Maintaining and updating the Management Plan as needed, with the appropriate approvals of signatories to this document;
- Approval of Technical Design Reports, Memoranda of Understanding and work plans for Run II Luminosity Upgrade subprojects;
- Establishing and maintaining mechanisms to carry out the Quality Assurance responsibilities of the Run II Luminosity Upgrade.

The Run II Luminosity Upgrade Project Manager, in consultation with the Head of the Accelerator Division may appoint Deputy Project Managers for appropriate areas.

RUN II LUMINOSITY UPGRADE PROJECT OFFICE

The Run II Luminosity Upgrade Project Office staff assists the Run II Luminosity Upgrade Project Manager in the administration of the Run II Luminosity Upgrade. It includes an Assistant Project Manager, a part-time (shared) Cost Administrator, and a part-time (shared) Schedule Administrator. The responsibilities of the Run II Luminosity Upgrade Project Office encompass the entire Run II Luminosity Upgrade.

RUN II LUMINOSITY UPGRADE LEVEL 2 MANAGERS

Run II Luminosity Upgrade Level 2 Managers (WBS 20.26.X) generate the cost-estimate, schedule, and resource requirements for their Subprojects. The Level 2 managers will provide information on cost, schedule and performance for the monthly reports and update their resource-loaded schedules monthly.

RUN II LUMINOSITY UPGRADE LEVEL 3 MANAGERS

Run II Luminosity Upgrade Facility Level 3 managers are appointed by the Run II Luminosity Upgrade Project Manager in consultation with the appropriate Level 2 Manager. They are responsible for the design, procurement, fabrication, installation, and commissioning of their Level 3 element. Level 3 managers document the scope and benchmarks of the Level 3 element by maintaining the relevant portion of the Run II Luminosity Upgrade Plan.

RESPONSIBILITIES OF OTHER FERMILAB DIVISIONS AND SECTIONS

The heads of supporting Divisions and Sections are responsible for supplying the necessary human resources, technical resources, space resources, administration of financial resources and evaluation of ES&H issues that relate to this.

- The Business Services Section (BSS) is responsible for assisting the Run II Luminosity Upgrade in the procurement of materials and/or services, inventory management of property and items acquired by Fermilab and legal advisement as appropriate. Whenever possible, fixed-price competitive procurement practices will

be used. After receiving appropriate approval, purchase requisitions are processed by the BSS Procurements Group.
- The Environment, Safety & Health Section is responsible for oversight of ES&H on the Fermilab site and provides the primary contact with DOE-FAO for matters related to site-wide ES&H. Support activities include safety training, assessments and monitoring plans.
- The Facilities Engineering Services Section provides engineering and design support for the Run II Luminosity Upgrade, including design, inspection, progress monitoring and payment approval for on-site construction activities.
- The Technical Division provides support in design and construction of magnets and other technical devices.
- The Computing Division provides support in the design, construction, and commissioning of accelerator instrumentation and controls.

OTHER SOURCES OF SUPPORT

Personnel resources from universities and from other laboratories are enlisted to provide support for the Run II Luminosity Upgrade under the leadership of the Project Manager.

A.3 Management Systems and Procedures

This Section describes systems and procedures that will be used to manage the cost, schedule and technical aspects of the Run II Luminosity Upgrade and the interactions that exist among them. Although various management procedures are described separately here, they are mutually supportive and will be used in an integrated manner. As the Run II Luminosity Upgrade evolves, our management systems may be modified in order to operate efficiently under changing conditions. Significant changes will be reflected in a revision of this document. Consequently, while the policy and objectives of each management system will remain fixed, the methods, techniques and procedures will be adapted to the needs of the upgrades.

REPORTING

This Section describes mechanisms of written communication within the Run II Luminosity Upgrade, including regularly issued reports and updates to management documents.

MONTHLY REPORTS

The Run II Luminosity Upgrade Project Manager will provide monthly report presentations to the Fermilab Directorate through the Run II Accelerator PMG. The summary content of these monthly report presentations will be available on the Run II Luminosity Upgrade web-site maintained by the PMG Chairman. The format of the monthly Run II Luminosity Upgrade Report may vary but the basic information will include:

- Upgrade Description
- Overview of Status
- Master Schedule and Milestones (with Critical Path milestones indicated)
- Funding Summary
- Narrative Highlights
- Variance Analysis
- Cost Performance Reports

REPORTING REQUIREMENTS FOR THE LEVEL 2 AND LEVEL 3 MANAGERS

The Level 2 and Level 3 managers provide monthly progress reports to the Run II Luminosity Upgrade Project Manager. Level 3 Managers also provide monthly updates of the Resource-Loaded Schedule (RLS) for their elements to the Run II Luminosity Upgrade Project Manager and the appropriate Level 2 Manager.

OTHER REPORTS

The Plan describes the technical benchmark of the Run II Luminosity Upgrade. The Plan will be updated and controlled following change approvals and for periodic external reviews. In addition, a set of technical documents (referenced in the Plan) is maintained electronically and is accessible via the World Wide Web.

MEETINGS

The following meetings are regularly scheduled to coordinate the efforts of the various elements on the Run II Luminosity Upgrade:

- Monthly meetings of the Run II Accelerator PMG.
- Weekly meetings between Accelerator Division Head and Run II Luminosity Upgrade Level 2 Managers (part of meeting of AD Management Team).
- Bi-weekly meetings of the Fermilab Run II Luminosity Upgrade Staff including Level 1, Level 2, and Level 3 Managers.
- Level 3 Managers are expected to hold regular meetings with their individual staffs.

A.4 Benchmarks, Control Levels, and Performance Monitoring

The benchmarks and control levels are defined in a two-tiered manner that provides change control authority at the appropriate management level. Procedures for making changes to the benchmarks are described in Section A.5.

The technical, cost, and schedule benchmarks are described in the Run II Luminosity Upgrade Plan of June 2003 and subsequent updates. While the Director's budget guidance for the Run II Luminosity Upgrades includes contingency levels described in the Resource-Loaded Schedule, the authorization to allocate contingency is reserved by the Directorate, with authorization to allocate contingency being granted to the Run II Luminosity Upgrade Project Manager either for specific scope change items, or as a small sum of "working contingency" at the cumulative $ 100 K level. The associated change control levels are outlined in Table A1.

Run II Luminosity Upgrade Change Control Thresholds	Fermilab Director, Run II Accelerator PMG	Run II Upgrade Project Manager
Technical	Changes that affect ES&H requirements. Out-of-scope changes to upgrade collider capabilities or impact accelerator systems.	Changes that do not affect ES&H requirements and do not affect upgrade scope.
Cost	Any increase by $ 100 K or assignment of contingency of $ 100 K to upgrade.	Draw on contingency up to assigned $ 100 K level (cumulative).
Schedule	Any change in the upgrade critical path or a primary milestone by more than 1 month.	Any change in a critical path for a sub-system or a lower level milestone by more than 1 month.
Personnel	Any increase in required FNAL personnel of 10 % relative to the Resource-Loaded Schedule.	Any change in Level 2 subproject personnel of 10% for the year.

Table A1**.** Benchmark Change Control Levels**.**

WORKING RESOURCE-LOADED SCHEDULE

The Run II Luminosity Upgrade Project Manager maintains a detailed working cost and schedule forecast that is updated monthly, using new information from subproject managers and from the Fermilab accounting system. The cost and schedule information covers all funded work including manpower, and is included at an appropriate summary level in the monthly report to the Fermilab Directorate. The working schedule shows projected dates for achieving milestones, taking account of actual progress to date.

Responsibility for the collection of information, updating of databases, and report generation is carried by the Run II Luminosity Upgrade Cost and Schedule Administrators.

BENCHMARK RESOURCE- LOADED SCHEDULE

The RLS is used as the detailed benchmark for monitoring and control within the Run II Luminosity Upgrade. The cost and schedule information goes down to detailed WBS levels, and uses the same cost and resource-loaded schedule base estimates that were presented in the Plan of June 2003 and subsequent updates and DOE reviews. The latest summary of the Cost Estimate is found in the latest monthly report.

Level 3 milestones are presented in Run II Luminosity Upgrade monthly reports as a basis for comparison with the working schedule.

Changes to the Resource-Loaded Schedule will be made in accordance with the change control process described in Section A.5.

VARIANCES

Monthly schedule and cost variances are computed and used as management tools to identify, analyze and rectify significant deviations from the detailed benchmarks as early as possible. Since the accounting will be based on MicroSoft Project, the earned value analysis will be accomplished at that commensurate level of detail and sophistication.

A.5 Change Control Management

Change Control Management refers to the process of proposing, approving, and making any changes to technical, cost and schedule benchmarks. The sequence of steps in this process is:

1. Proposing any change. This is done by submitting a Change Request (CR) to the Run II Luminosity Upgrade Project Manager.
2. Approval of the CR. Any CR will be reported to the Run II Luminosity Upgrade Project Manager. If the impact of the requested change exceeds the thresholds described in this Section, the Run II Luminosity Upgrade Project Manager will submit it to the Run II Accelerator PMG for consideration. If approved, the Chairman of the PMG will submit it for approval by the Fermilab Director.
3. Changing the benchmark after approval of the CR. This will be done by the Run II Luminosity Upgrade Cost and Schedule Administrators. Technical aspects of approved changes will be documented in Technical Notes, or in documentation associated with technical reviews.

The following sections describe steps 1 and 2 in more detail.

MAKING A CHANGE REQUEST

A CR should be submitted by a subtask manager in any of the following kinds of situations:

1. A technical change in the design is proposed which is likely to have any of the following:
   - Significant effects upon the system performance, or require a revision of the Technical Notes.
   - Schedule impact such that a class A milestone on the critical path per phase might be shifted by more than 30 days.
   - Schedule impact such that a class B milestone <u>not</u> on a critical path per phase might be shifted by more than 60 days.
   - Cost impact at the level of 20% of the subsystem to which the change is to be made.

Note that most technical changes that arise from refinements of engineering designs or from Value Engineering studies are not expected to require CRs.

2. A significant cost benchmark change is indicated by a new estimate or because of actual bids on a large purchase, actual experience with work accomplished to date, or accumulation of cost variances in smaller tasks and purchases. "Significant" should be construed in terms of the thresholds using about 25% of the PMG consideration level.

3. A significant schedule change is indicated, arising from a new estimate or actual bids on key purchases, or experience gained, or accumulation of smaller schedule variances. A threshold of 30/60 days as described above should be used.

4. An administrative change is planned which will require a modification or restructuring of the WBS. Implementing such major changes will require considerable effort by the Run II Luminosity Upgrade Support Staff.

CRs should be submitted using a standard form (Fig. A3) and identified by a log number. They will be maintained in an accessible file in the Run II Luminosity Upgrade Project Office and will be updated with approval and status information.

APPROVAL OF CHANGE REQUESTS

The following two sub-sections show the benchmarks and change control thresholds for approval by the Directorate (as advised by the PMG, which functions as the Change Control Board).

TECHNICAL BENCHMARK CHANGES

The technical scope of Run II Luminosity Upgrade is outlined in the Plan and electronic web-links to technical references are provided therein. Level 3 managers are encouraged to keep their respective Technical Notes updated as necessary.

RUN II UPGRADES – CHANGE REQUEST

1) DATE:	**2) LEVEL 3 WBS:**	**3) ORIGINATOR:**
January 20, 2004	26.3.4	Jeff Spalding

4) WBS DESCRIPTION OF PRIMARY AFFECTED TASKS:
The commissioning plan for the Recycler has been developed and integrated into the Run II Upgrade Plan. (WBS 26.3.4) This change will be implemented in v2.0 of the plan.

5) TECHNICAL DESCRIPTION AND PRIMARY MOTIVATION OF CHANGE :
The updated Recycler plan consists of two sections. The first details commissioning of the machine to a performance level at which electron cooling can itself be commissioned in the Recycler. This is achieved before summer 2004, when the electron cooling beamline will be installed. The second section outlines upgrades to systems in the Recycler which are required for efficient operation at large stack sizes.

The original plan included a representative level of resources for commissioning the Recycler, without a detailed plan. No costs for upgrades were known at that time. This change includes the M&S costs for the upgrades and an improved labor estimate.

These upgrades are installed in the summer 2004 shutdown. The systems to be upgraded are LLRF and diagnostics ($267K base), spare kicker magnet ($375K base) and stochastic cooling diagnostics ($133K).

6) ASSESSMENT OF COST IMPACT (identify any change in resources needed)
Estimated M&S Cost Change ($K):
Increase = $775K (M&S base), $1085K (M&S with contingency)
Estimated Labor Cost Change ($K):
New labor estimate = $1,129K, previous estimate = $786K, increase = $343K

7) ASSESSMENT OF SCHEDULE IMPACT AND AFFECTED MILESTONES (identify slip or stretch of work or change in plan):
These upgrades will be implemented in FY04 and be complete before the Recycler is commissioned along with electron cooling into HEP.

The milestone for the Recycler commissioning to be ready for electron cooling is one month earlier than in the previous version.

26.3.4.9.1.6 Recycler Commissioned for Electron Cooling: 7/2/04 (v1.0) becomes 6/1/04 (v2.0)

8) SECONDARY IMPACT AND OTHER COMMENTS:
None.

9) APPROVALS
Level 2 Project Manager ______________________ Signature / Date
Level 1 Project Manager William J. Spalding 1/30/04 Signature / Date

10) DIVISION/DIRECTOR APPROVAL
✓ APPROVED **O DISAPPROVED** Roger L. Dixon 1/30/04
Signature/date

✓ APPROVED **O DISAPPROVED** S. D. Holmes 1/30/04
Signature/date

Fig. A3. Example of a Change Request (CR) Form.

COST AND SCHEDULE BENCHMARK CHANGES

Cost Changes may involve either the transfer of money only from one WBS element to another (within the total cost estimate in the Plan), or may include the utilization of contingency. Change control levels for transferals are indicated in Table A1. All contingency is held by the Fermilab Director and any utilization of contingency is subject to approval by the Run II Accelerator PMG, subject only to the $100K accumulation reporting limits discussed below.

Any change exceeding $100K requires PMG consideration and Director's approval prior to commitment. For CR's for which the utilization of contingency is less than $100K, the Run II Luminosity Upgrade Project Manager will submit a Change Request for consideration and advisement by the PMG when accumulated cost changes exceed $100K or when accumulated schedule changes cause a Level 3 milestone to be delayed by more than 60 days. In practice, the $100K accumulation limit permits the commitment of financial resources from contingency up to the $100K limit prior to consideration by the PMG or the Directorate.

Upon approval of a Change Request, the Resource-Loaded Schedule will be revised accordingly. Change control thresholds are shown in Table A1.

FINANCIAL MANAGEMENT AND WORK AUTHORIZATION

Budget codes will be established by the Fermilab Budget Office following the WBS structure and assigned at the most appropriate level consistent with the tracking and reporting requirements established for this upgrade. The accumulation of costs in these accounts will be initiated through purchase requisitions (M&S costs) and SWF cost transfers. Purchase requisitions originate with the engineering and scientific staff assigned to the various sub-systems. Signature authority levels will be provided to the Fermilab Business Services Section by the Run II Luminosity Upgrade Project Manager to assure that only authorized work is initiated.

At any time, the contingency for the Run II Luminosity Upgrade is the difference between the total cost estimate in the Resource-Loaded Schedule and the current Estimate at Completion (EAC). Release of contingency funds will require approval of the Fermilab Director.

Authorized work is identified in the RLS. Initiation of authorized work is controlled through the requisition approval process and regular communication within the management structure described in Section A.2. Monitoring of authorized work is achieved through monthly report documentation and cost report analyses, as well as regular managerial communication.

QUALITY ASSURANCE

The most important aspect of Quality Assurance is the review process to assure that what is being proposed and built will effectively meet the needs of upgrading the Collider Luminosity. There are two types of reviews that help accomplish this goal, both internal to the Run II Luminosity Upgrade organization, and external.

Internal Reviews:

The Run II Luminosity Upgrade Plan specifically schedules milestones for the evaluation of vital elements, such as the Tevatron Upgrade Plan and the Recycler Commissioning Plan. In addition, Technical Reviews are required of many of the individual sub-projects, at the requirements, specifications, conceptual design, and technical component review stages.
These reviews are carried out by teams of experts, independent of the element being reviewed, from within the Accelerator Division, from other Fermilab Divisions and Sections, or from other Laboratories. These reviews are commissioned by the Head of the AD and the committee reports back to the Head of the AD. The Project Manager and L2 managers are responsible for defining and accomplishing the timely follow-up actions in response to the review recommendations. The Run II Luminosity Upgrade Project Manager may initiate additional design reviews as appropriate.

External Reviews:

Independent assessments by qualified individuals comprise a fundamental quality assurance process for the Run II Luminosity Upgrade. The results of such assessments can help to identify problems, suggest solutions and provide for overall improvement. Examples of reviews of the Run II Luminosity Upgrades that are conducted on a periodic basis are those by the Fermilab Accelerator Advisory Committee, Director's (Temple) Reviews, and reviews by the Department of Energy. The Fermilab Director will, at his discretion, call for additional reviews of the Run II Luminosity Upgrade.

A.6 Environment, Safety & Health

The design, construction, commissioning, operation, and de-commissioning of all Run II Luminosity Upgrade systems will be performed in compliance with the standards in the Fermilab ES&H Manual, and all applicable ES&H standards in the Laboratory's "Work Smart Standards" set. In addition, all related work will be performed in compliance with applicable federal, state and local regulations. Except for the new Pelletron accelerator for electron cooling (funded under prior years Equipment and AIP civil construction), there are no special hazards, other than those commonly encountered in the operation, maintenance, and regular improvement of existing accelerator systems. The Pelletron installation has had a Safety Analysis Document (SAD) and Radiation Shielding Assessment completed for testing operations in the Wide-band Lab. The SAD and

Radiation Shielding Assessment are being prepared for the actual installation in MI-31. The regular ES&H organizations already in place, namely the AD departmental organizations and ES&H procedures, the AD ES&H Department, and the Fermilab Environment, Safety & Health Section provide sufficient ES&H support for all Run II Luminosity Upgrade activities. Fermilab follows Integrated Safety Management. Each person on the Run II Luminosity Upgrade staff is responsible for following good ES&H practices in the course of his or her own work.

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